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8. Papers should average about 12,000 words in length and should be no longer than 18,000 words. As an approximation, each full page of typed text, table, or illustration is the equivalent of 300 words.

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SURVEYING AND MAPPING DIVISION

Proceedings of the American Society of Civil Engineers

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Paper 1842 November, 1958 SU 3

Journal of the
SURVEYING AND MAPPING DIVISION
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HIGHWAY AND BRIDGE SURVEYS: PRELIMINARY BRIDGE SURVEYS[a]

Progress Report of the Committee on Highway and Bridge Surveys of the Surveying and Mapping Division
(Proc. Paper 1842)

1. Surface Surveys

General

The preliminary engineering phase in the development of a bridge crossing is not generally as well defined as in the case of highway work on land. The reconnaissance often becomes merged with the preliminary operation, particularly in the cases of many present-day water crossings where exact alignment and location are practically dictated by existing bridges or road systems. However, considering the problem in general, the reconnaissance has established the need for the water crossing within a very limited zone, the exact alignment to be refined by further study of the land and bay bottom features and the subsurface geology.

The surface surveys are the first operation of the preliminary phase, these being necessary for the location of the land and water features, the hydraulic studies and the subsurface explorations. After an approximate alignment of the water crossing and approaches is drawn on U.S.C. & G.S. Charts, U.S.G.S. topographic maps or aerial mosaics, the entire control system should be designed. Existing coordinated hubs and bench marks will obviously determine to a large degree this control system. With most projects, time is very limited at this stage, with authorization of some sort obtained to proceed with the work and already some commitments made for the start of detailed plans and construction. Accordingly, it generally behooves the engineer to make full use of available control, relying on limited accuracy of the existing points which will probably suffice. However, the preliminary control system can invariably, at a later date, be made a part of or common to the location or construction control system, which is advisable not only to reduce the work entailed, but to enable a direct check between the preliminary and final alignment data.

Note: Discussion open until April 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1842 is part of the copyrighted Journal of the Surveying and Mapping Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. SU 3, November, 1958.

a. This paper will form the basis for a chapter in a proposed ASCE Manual of Engineering Practice.

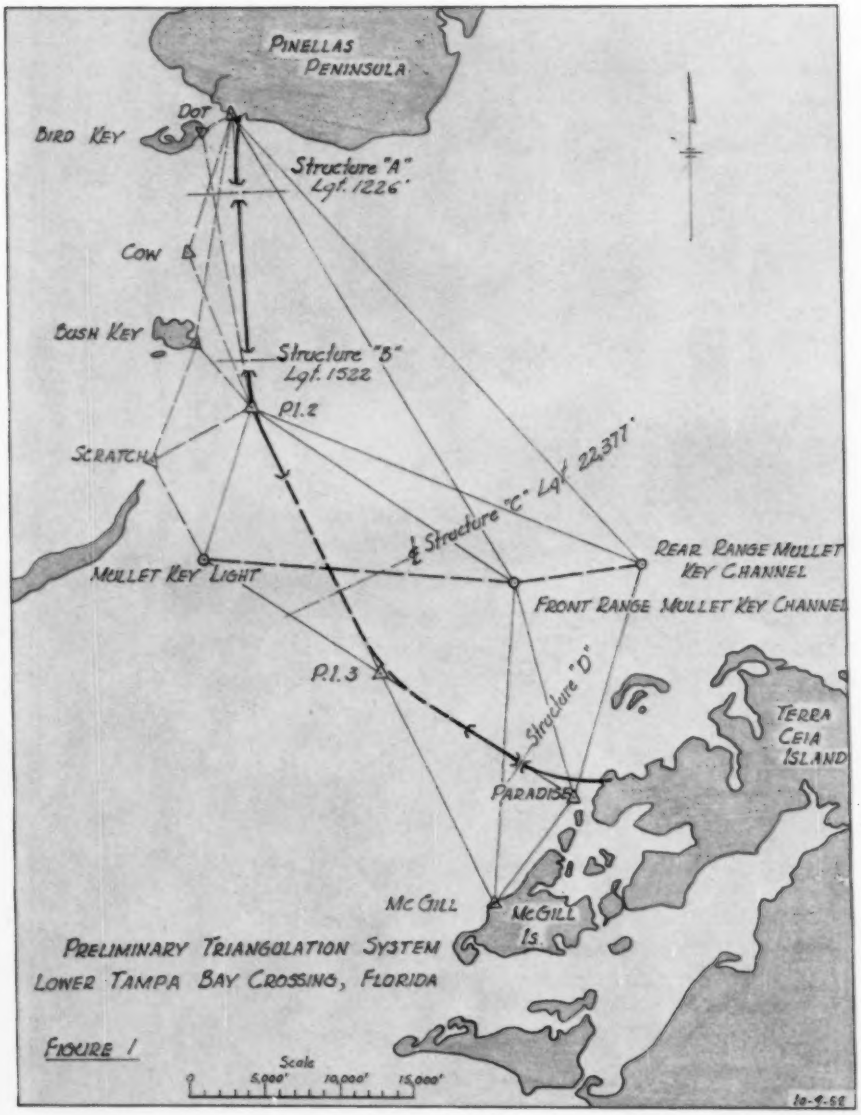
Alignment Control

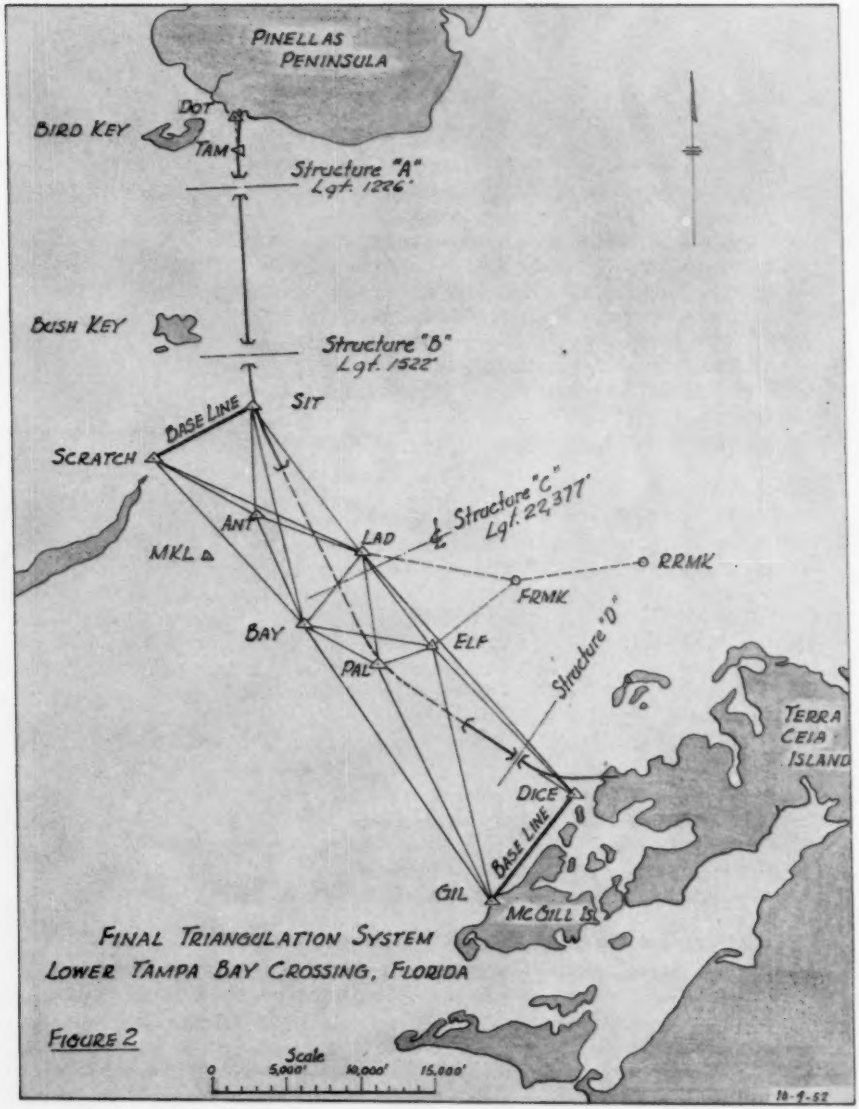
The preliminary horizontal control system for a water crossing will generally consist of a simple triangulation network, either with measured base line or utilizing known distances from other sources, and connecting with simple alignment traverses for the approaches. The approaches will not be stressed in this discussion, in that surveys for lengthy approaches will be the same as highway surveys covered in Part A.

The illustrations, Figs. 1, 2 and 3, show the preliminary control systems used prior to the construction on the Lower Tampa Bay Crossing in Florida and the Hampton Roads Bridge and Tunnel in Virginia. These two projects involved 15-mile and 5-mile water crossings, respectively, constructed in 1955 and 1957, and indicate well-designed horizontal control systems, which were later incorporated into more elaborate and refined systems for construction. On projects as long as these, with time generally of the essence, it often becomes extremely difficult to give the necessary survey control without the benefit of survey control towers on land and in the water, which must come later, time and funds permitting. Also illustrated, Figs. 4 and 5, are two typical systems for shorter crossings, namely, the Cortez and Palma Sola Bridge Crossings on the West Coast of Florida. Bridges of this length, one to two miles, can generally be handled with a single base line with a simple quadrilateral.

The preliminary horizontal control systems need not provide extreme accuracy: generally, about third order is sufficient. This means that existing coordinated locations may often be used in lieu of measured base lines, even if this entails running random traverses a considerable distance to make them usable. Of course, an ideal solution is to incorporate the known points into the triangulation net. In the case of the Lower Tampa Bay Crossing illustrated, three aids to navigation were used about which a simple network was established. This is often possible on long water crossings and most aids to navigation are located by the Coast & Geodetic Survey or the Corps of Engineers to about third order accuracy. It is not always practical to occupy these aids, many of them being too small or the higher ones being too flexible to permit accurate observations. If it is possible to set up a theodolite on them, permission can invariably be obtained through the U. S. Coast Guard. Use of such existing control thus eliminates the need for measured base lines, which is often too time-consuming at this stage of the work; but the engineer should realize that aids to navigation are at times replaced or shifted in position and he should make certain his control data agrees with the present position of the aids.

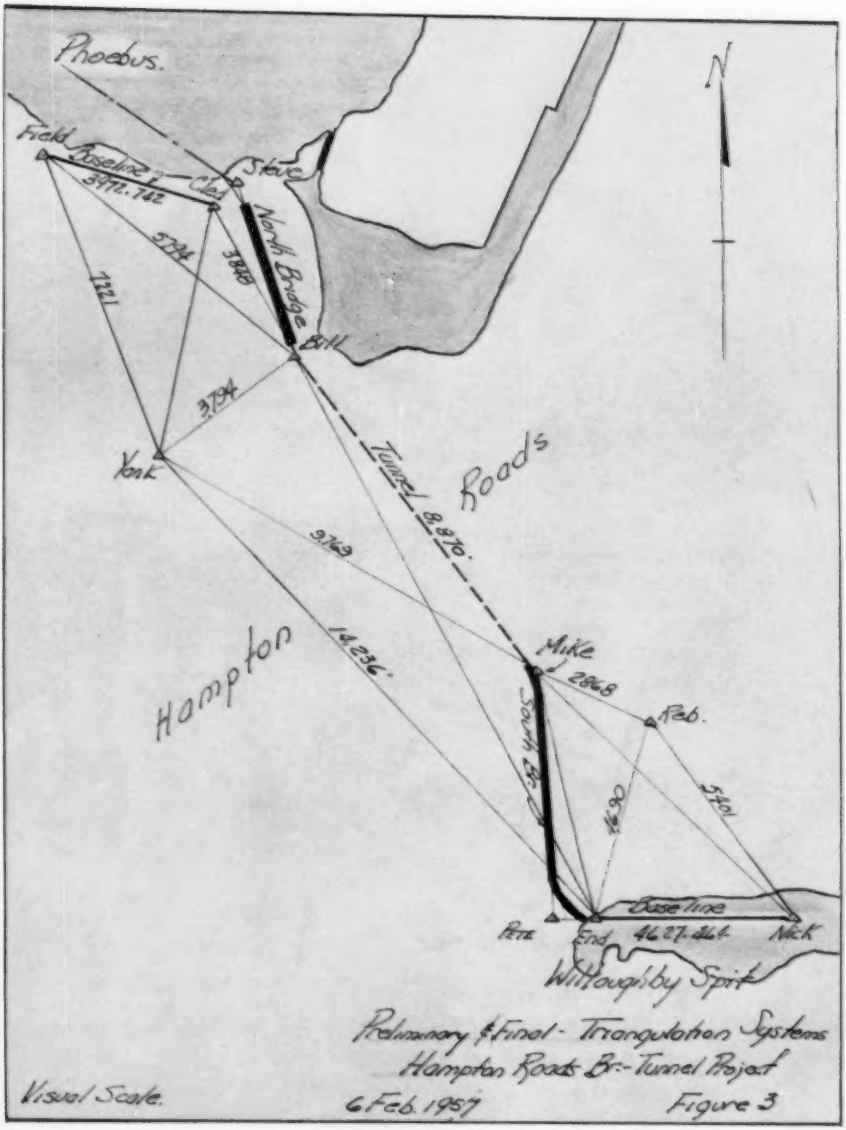
Occasionally, the site of the crossing may occur in an area relatively free of established survey control, or what is more frequent, in an area where existing control was established years ago and storms or hurricanes have destroyed or moved the hubs. There is very little recourse then but to establish one or more measured base lines and evolve a triangulation net about these. Once in a lifetime, on smaller crossings, an engineer is blessed with having an existing bridge, trestle or causeway more or less paralleling the new alignment. This, of course, provides an ideal opportunity to have a measured base line on the nearby structure upon which to build the control network.


PINELLAS PENINSULA
DOT
BIRD KEY
Structure "A"
Lgt. 1226'
COW
BASH KEY
Structure "B"
Lgt. 1522
P1.2
SCRATCH
Structure "C" Lgt. 22,377'
MULLET KEY LIGHT
REAR RANGE MULLET KEY CHANNEL
FRONT RANGE MULLET KEY CHANNEL
P.1.3
Structure "D"
TERRA CEIA ISLAND
PARADISE
MC GILL
McGILL IS.
PRELIMINARY TRIANGULATION SYSTEM
LOWER TAMPA BAY CROSSING, FLORIDA
FIGURE 1
Scale
0 5,000' 10,000' 15,000'
10-9-58



FINAL TRIANGULATION SYSTEM
LOWER TAMPA BAY CROSSING, FLORIDA

FIGURE 2


Phoebus.
Field
Baseline
3971.782
Clel
State
North Bridge
3888
3734
1721
3194
Yonk
Tunnel 8376'
Roads
3149
Hampton
14236'
Mike
2868
South Br.
Feb.
5701
1630
Base line
Pete
End
4627.464
Nick
Willoughby Spit
N
Preliminary & Final - Triangulation Systems
Hampton Roads Br.-Tunnel Project
Visual Scale.
6 Feb. 1957
Figure 3

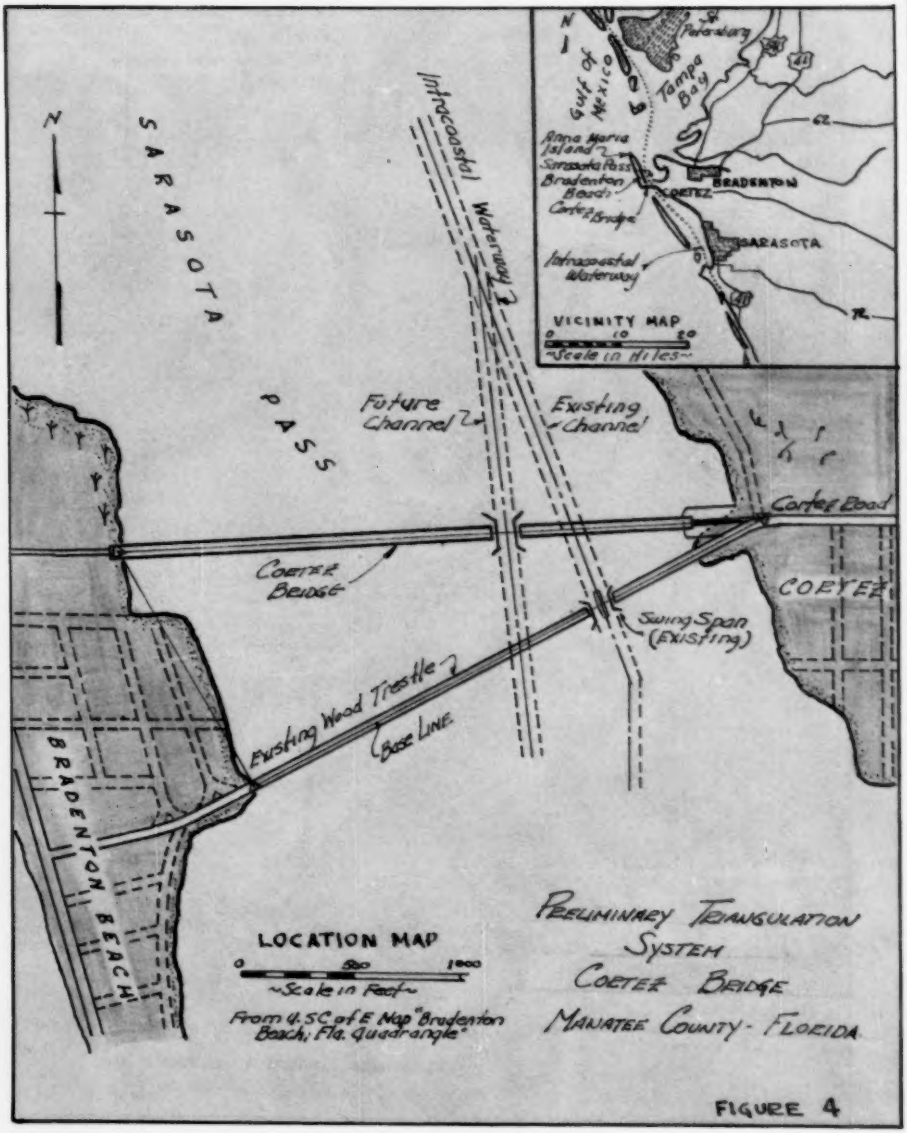
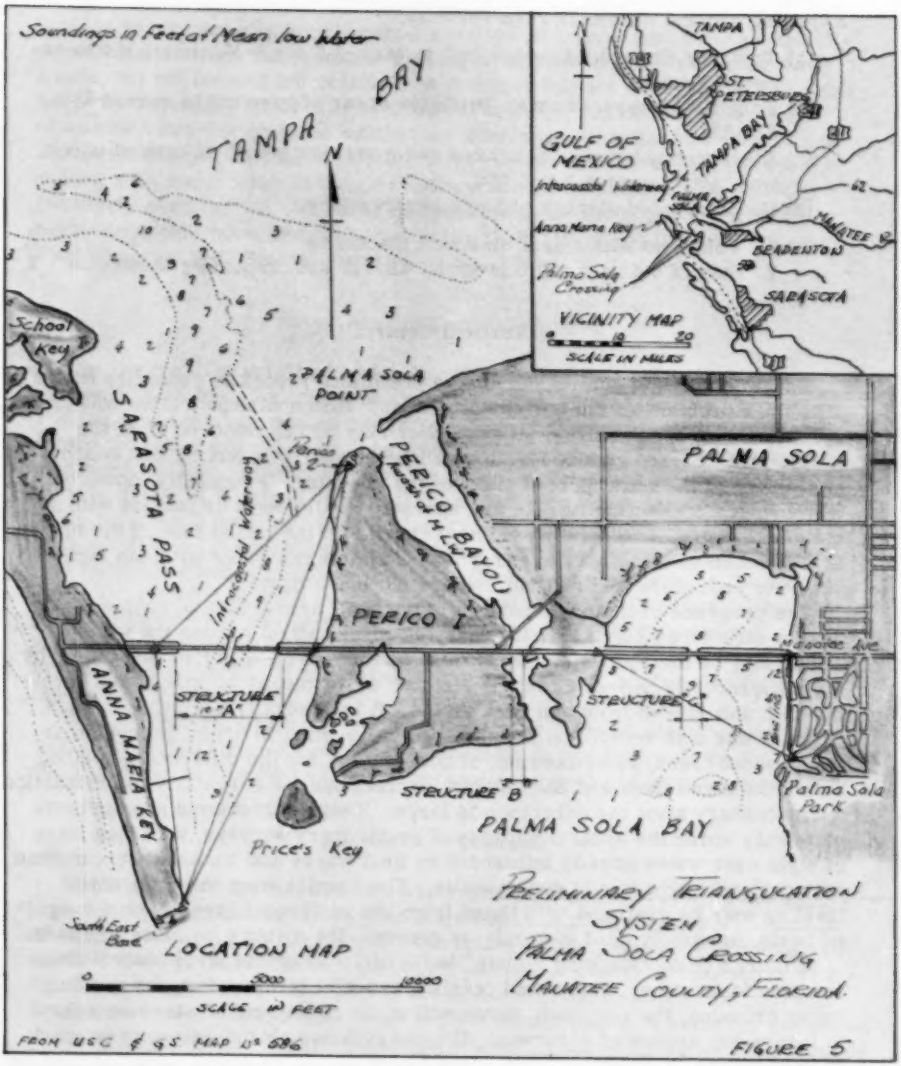

N
SARASOTA
PASS
Intracoastal Waterway
Future Channel
Existing Channel
Corteż Road
COETEZ BRIDGE
Swing Span (Existing)
COETEZ
Existing Wood Trestle
Base Line
BRADENTON BEACH
LOCATION MAP
0 500 1000
~Scale in Feet~
From U.S.C. of E. Map "Bradenton Beach, Fla. Quadrangle"
PRELIMINARY TRIANGULATION SYSTEM
COETEZ BRIDGE
MANATEE COUNTY - FLORIDA
VICINITY MAP
0 10 20
~Scale in Miles~
St. Petersburg
Tampa Bay
Gulf of Mexico
Anna Maria Island
Sarasota Pass
Bradenton Beach
Cortez Bridge
BRADENTON
SARASOTA
Intracoastal Waterway

FIGURE 4


Soundings in Feet at Mean low Water
TAMPA BAY
TAMPA
N
SAFASOTA PASS
School Key
PALMA SOLA POINT
Ponds
Intracoastal Waterway
PERICO BAYOU
Mouth of H.W.L.
PERICO I
PALMA SOLA
Manatee Ave.
ANNA MARIA KEY
STRUCTURE "A"
STRUCTURE B
STRUCTURE
Price's Key
PALMA SOLA BAY
Palma Sola Park
South East Base
LOCATION MAP
0 5000 10000
SCALE IN FEET
GULF OF MEXICO
TAMPA BAY
ST PETERSBURG
Intracoastal Waterway
PALMA SOLA
Anna Maria Key
MANATEE R.
BRADENTON
Palma Sola Crossing
SARASOTA
VICINITY MAP
0 10 20
SCALE IN MILES
PRELIMINARY TRIANGULATION SYSTEM
PALMA SOLA CROSSING
MANATEE COUNTY, FLORIDA.
FROM U.S.C. & G.S. MAP NO 686
FIGURE 5

Standards for Alignment Control

Third order accuracy for preliminary triangulation control entails the following general minimum requirements:

(a) Triangle closure: Average, not to exceed 5 sec.—Maximum not to exceed 10 sec.
(b) Base line measurements: Probable error of base not to exceed 1 in 250,000.
(c) Discrepancy between computed and measured length of base of check line, not to exceed 1 in 5,000.
(d) Recommended number of angle observations:

1. Positions with 1 sec. direction theodolite 4
2. Sets of 6 direct and 6 inverted with 10 sec. repeating theodolite 2

Vertical Control

Level or vertical control during the preliminary work is generally not as difficult a problem as the horizontal control. Reconnaissance often will uncover existing bench marks, although they may be far removed from the bridge site. Closed circuit leveling will be needed to establish new benches convenient to the work on both sides of the crossing. Frequently, however, with bridges connecting remote and sparsely settled keys or islands with a mainland, there is no existing vertical control on the island side of the bridge. It then becomes necessary to carry levels across the water by some fairly accurate procedure that will not require too much time.

The presence of islands, shoals, dredge spoil areas, aids to navigation or nearby structures may facilitate carrying level control across the water. These may be used as "stepping stones" and the leveling performed either by the reciprocal or "River Crossing Method" or by means of differential leveling with unbalanced front and back sights. It is generally advisable in such cases to use both reciprocal and differential leveling in order to provide an independent check, remembering, of course, that for the differential method with unbalanced front and back sights, corrections for curvature and refraction are necessary when the unbalance is large. These corrections are approximate only under the usual conditions of preliminary surveys, with long lines of sight over water greatly influenced by heat waves and wind, but this method with care will give fair to good results. The results from the differential leveling may be averaged with those from the reciprocal leveling on a weighted basis, or simply used to verify, in general, the solution by other methods.

If there are no "stepping stones" to facilitate carrying level control from one side to the other, reciprocal leveling can still be used, but, for the long water crossing, the very long sights will make considerable care necessary to insure any degree of accuracy. The instruments should be set up on good vantage points, if available, with some height above the water. Special targets should be constructed which can be accurately held and raised or lowered. If the crossing is several miles or longer, it is advisable to do the work at night with target lights. Accurately adjusted instruments must be used, either precise levels or precise theodolites such as the Wild or Kern which have excellent precision when used as levels.

Another means of extending level control from one side of a crossing to the other is by gages set up in the water at both shores and using the water level as a medium. This can be an accurate procedure, but obviously is affected by many factors, not all of which can be controlled. The method in brief is to take exactly simultaneous readings at both gages, over an extended period, and average the results. The gages should be sheltered from wave action, but not located too remotely in coves or bayous where the water level might be adversely influenced by tidal currents or wind action. Readings should be taken during calm weather or when wind directions are normal to the line of the gages, this to eliminate the effects of wind-created tides. On waters with lunar tides, the gage readings should be taken during slack or relatively slack water. Valuable information on methods and equipment for performing this work are contained in the U. S. Coast and Geodetic Manual of Tide Observations, Special Publication No. 196.

Standards for Vertical Control

The degree of precision for this level control at this stage is largely a matter of judgment, depending on the circumstances and length of crossing. For the land leveling, second order accuracy is adequate: all level circuits should originate and close back on first or second order level bench marks; maximum closing error of any line or circuit should not exceed about 0.035 ft. $\sqrt{M}$ where M is length of circuit in miles. For the water crossing when using reciprocal leveling, differential leveling with unbalanced sights, tide gage leveling or combinations of all of these methods, the accuracy attained may be limited and it might be mandatory to accept elevations to the nearest 0.2 ft. or even 0.5 ft. until control towers, piers, etc., will simplify the problem later. For bay bottom profiles and subsurface explorations, elevations to these precisions, even to the nearest 1.0 ft. for bay bottom profiles, are not unreasonable. If sizeable and expensive water approaches to the bridge are involved, level accuracy of about 0.1 ft. is in order.

With the control systems, both horizontal and vertical, designed and established in this general fashion, it is possible to proceed with the balance of surface surveys as well as the hydrographic and geologic investigations.

Approach Topography

The immediate approaches to a water crossing are surveyed in the same fashion as the typical highway. The alignment control generally will consist of simple traverses connecting with the triangulation network which spans the water crossing. A complete topographic survey is generally necessary with the end product an accurate map of the actual terrain itself, the contours, drainage characteristics, etc., together with the property boundaries and the existing structures. This must then be supplemented by research into property records, assembling all available record plats with property line locations, present owners, etc. This recorded data may or may not coincide with actual survey data obtained from the site, all of which may require additional research and field surveys.

Closely connected with this is the need for a continuous centerline profile with cross sections taken to the full width of the right-of-way at every 100 ft. station and half-station, or as local conditions dictate. This work may be

relatively simple as in rural or remote areas, or very involved when the bridge approaches occur in a heavily populated and built-up area. The subject will not be covered in detail here, in that it has been more properly included in Part A. Also, in the case of bridge approaches in metropolitan areas, reference should be made to the A.S.C.E. Manual of Engineering Practice No. 10, "Technical Procedure for City Surveys".

Aerial Surveys

The usefulness of photogrammetry for the preliminary engineering planning of the large scale highway project is already an established fact. The aerial survey in this stage of the work may either supplement ground control and mapping obtained by the usual ground survey methods, or may be practically sufficient within itself and require only the use of existing landmarks for ground control as plotted on state or federal maps. In the latter case, it may be necessary, after the aerial photos have been taken and studied, to establish some additional or confirming elevations and coordinates for some of these landmarks. In any event, the aerial survey can generally provide the necessary topography to the required accuracy in much less time than ground surveys. The added cost for this time advantage is generally moderate; as a matter of fact, on some types of terrain such as mountainous areas, the aerial survey will not only be quicker but cheaper as well.

The details of photogrammetry applied to highway work are treated elsewhere. The average bridge crossing, with limited approach highway connections, generally does not warrant the aerial survey, or at least the elaborate aerial survey leading to corrected aerial mosaics. However, in such cases, it is often advisable to take a few aerial photographs, vertical or oblique, and use them as developed without making any attempt at ratioing them to correct for altitude changes of the airplane, etc. Such photographs will be very helpful in establishing the preliminary alignment, not only of the highway but of the bridge crossing. They will also assist in rough terrain with the design of the survey control systems by pointing out the bog and jungle areas to be avoided, the likely locations for base lines and survey control points, the logical sites for temporary survey camps and boat docks, etc. These informal aerial photographs can easily be taken by a good photographer in a chartered light airplane and are well worth the moderate costs involved.

2. Hydrographic Surveys

General

Establishment of the horizontal and vertical control systems makes it possible to proceed with the survey of the water crossing itself. This will include a hydrographic survey to determine the hydraulic or flow characteristics of the water at the proposed crossing as well as the channel or bay bottom containing the water; also a geologic survey of the subsurface foundation conditions which will be treated later in this chapter. The nature of the hydrographic data required will, of course, vary somewhat with the type of crossing, the location and the exposure of the structures. In general, it is necessary to obtain information on the water datum, tide or river flood stages, tidal and river or other currents, ice and water erosion characteristics, etc., together

with a complete bay or river bottom profile with cross sections. Many of our long present-day water crossings involve embankment or causeway sections placed hydraulically, which generally means some underwater study for material borrow areas.

Some of this information may be available in already published documents and hence it behooves the engineer to first exhaust these sources before undertaking the actual field survey. For coastal areas, the U. S. Coast & Geodetic Survey Charts and Tide Tables are invaluable; also state and federal publications on shore erosion whenever they exist for the particular area. Similar data are generally available for bridges crossing rivers, lakes, or canals, and are published by the U. S. Corps of Engineers, U. S. Geological Survey, U. S. Lake Survey, and state agencies. Aerial mosaics, if prepared for extended highway approaches, will be of value for the water crossing. If the project does not warrant an aerial survey with mosaics, a few aerial photographs, either vertical or oblique, will facilitate this stage of the work. These photos generally will give a good preliminary concept of shoal areas and channels, particularly in southern coastal waters with various bottom growths and water colors.

Datum

Bridges crossing coastal and other navigable waterways are controlled by the Department of the Army. The Army permit will stipulate the requirements to be met by the bridge structure: if a navigable waterway is to be crossed, the minimum horizontal and vertical clearances for shipping will be indicated. The vertical clearance is generally given as a number of feet above Mean Low Water for the East Coast of the U. S. or Mean Lower Low Water for the West Coast, using the nearest reference station to determine the M.L.W. or M.L.L.W. datum. The U. S. Coast and Geodetic Tide Tables will define the reference station used and equate the M.L.W. or M.L.L.W. datum to the Mean Sea Level datum. The reader should also consult the U. S. Coast and Geodetic Manual of Tide Observations, and Tidal Datum Planes, Special Publication No. 135, for further information on the various tide data.

In this manner, the usual bridge crossing coastal waterways will involve two separate datums to be considered during the hydrographic survey and the vertical control system in general. The M.S.L. datum of 1929 is the one common reference datum regardless of location, and all vertical control should ultimately be tied into this. The M.L.W. or M.L.L.W. datum is a variable, in that it constitutes a mean of certain low water stages over an extended period for a particular location. For this reason, it is necessary, when stating minimum vertical clearances above M.L.W. or M.L.L.W., to refer to a specific reference station and the period of the records. In all probability, this reference station is not at the exact site of the bridge; actually it may be several miles distant. Because of this, and also on extremely long water crossings, such as the Tampa Bay Bridge covering 15 miles, there will be differences in M.L.W. or M.L.L.W. between the ends of the bridge and the nearest reference station. These differences may be nominal and since it will be impossible to determine them accurately without extensive research, it will probably be necessary to neglect them and use one M.L.W. or M.L.L.W. datum for the entire project, establish its equality to M.S.L. and then use M.S.L. for all level control work.

A similar condition generally exists for bridges crossing rivers or other inland bodies of water. Again, the M.S.L. datum will be used, but there may also be another local datum to consider, particularly if the waterway is navigable and a vertical clearance is prescribed. Vertical clearance for river bridge crossings often will refer to a certain river flood stage; giving the actual flood water level during a certain year or for a specified stage based on flood frequency studies, and the problem is similar to that discussed for M.L.W. The U. S. Corps of Engineers and the U. S. Coast and Geodetic Survey Charts and Bulletin will provide the basic information for review of this.

Tide and Current Studies

Water Levels

Some quantitative knowledge of the water levels is important in the design of the bridge, whether the crossing is over coastal or inland waters. Considerable data on this are again available in published bulletins, but generally these must be supplemented to some extent by field measurements. Tide ranges must be known, including spring and mean tide elevations. Local knowledge and physical evidence of extremely high or low tides should be determined. Often times there are no officially published data on high tides resulting from storms or hurricanes, and local evidence can be invaluable. The apparent changes in hurricane trends and patterns on the East Coast of the U. S. should be included in any review of tide water levels for projects contemplated in this area. The effect of hurricanes on tide levels may require special study beyond the limitations of a field survey.

The same general information is necessary for inland water crossings, especially for river crossings. Tides will have little or no effect on the river levels, except for some of the large estuary rivers near the coast. The seasonal changes in river water level are the important ones, as caused by flood and drought climactic conditions. Flood water stages 30 or 40 feet above normal, or river pool levels are not uncommon on some of our rivers as the Mississippi and the Missouri, and such fluctuations become important design considerations. Much of this can again be obtained from published data, but field research is also in order.

Water Currents, Ice and Erosion Conditions

It may also be necessary to study the water currents in addition to the water levels. Again the problem and required field work will vary considerably, depending on the type of bridge and the location. In some instances, such as moderately deep rivers with slow to moderate currents, with the entire crossing consisting of bridge structure supported by piers, current considerations may be of little or no consequence. About the only adverse effect of currents at such a crossing might be the bottom scour and its effect on pier stability. There are other water crossings, however, which entail considerable detailed study of currents and general hydraulics. Some of our present-day, long water crossings consist of combinations of bridge structures and hydraulic embankments, which often constitute constrictions to the flow of water, will influence current velocity and direction, and introduce serious erosion currents affecting the hydraulic embankments.

In northern climates, the effects of water currents may be seriously complicated by ice conditions. The unbroken sheet ice which can be so critical in the design of dam structures and result in enormous pressures along the dam is not generally so significant for the bridge structure which can be provided with ice-breaking piers or similar devices. However, the occurrence of massive ice floes which build up to great heights of "ice gorges" can be much more critical for the bridge, both for the water piers and those piers or abutments near the waters edge. A good example of the destructive powers of such conditions is the original Rainbow Arch Bridge near Niagara Falls, which collapsed when ice gorges destroyed the bridge abutments at the shorelines. Accurate information on all of these conditions should be gathered from published data and field observation for use in the design of the structure.

Many effects of water currents and ice conditions can become important design considerations and realization of them enables a more intelligent preliminary field investigation. Some general considerations are:

(a) Additional lateral loading on bridge piers resulting from water currents. High water velocities coupled with winter ice conditions may constitute important pier stability and erosion factors.
(b) Bottom scour caused by water current and the effects on pier embedment and stability.
(c) Shoreline erosion or accretion caused by water currents.
(d) Constriction to the river or tidal channel resulting from the construction of bridge piers and embankment sections. This constriction may adversely affect (a), (b) and (c) factors and make necessary additional ice protection, bottom rip rap and revetments, bulkheads and rip rap along the embankments, and other similar costly construction. If accretion or deposition results from the new structure, existing ship channels, oyster beds, tide flats, etc., may be seriously shoaled.

Again, considerable published information is available and should be exhausted before proceeding with an extensive current survey. Very often the published information will be sufficiently complete and accurate for the analysis of the hydraulics of the crossing. Generalizations and approximations are necessary and hence extreme accuracies are not essential. For coastal areas, the U. S. Coast and Geodetic Current Tables, Tidal Current Charts (for major harbors), Tide and Current Surveys, Special Publications of various numbers, and United States Coast Pilot should be consulted. For inland waters, the U. S. Corps of Engineers has many special publications, including the Harbor Series, giving important general information on our major ports. The U. S. Geological Survey has published many reports, water-supply papers and circulars containing information on basic stream flow data, outstanding floods, flood-frequency relations and hydraulics of flow in natural channels and through bridge constrictions.

Current Measurement

The measurement of current velocities and directions is possible with many devices and it is suggested that the U. S. Coast and Geodetic Manual of Current Observations be reviewed. Much of the information contained in this publication is on a more elaborate scale than required by an engineering preliminary survey, but nevertheless it is an excellent guide.

The simplest method is the use of floats introduced into the current stream with the location of the floats controlled by means of an attached tagline or by means of instrument work from the shore or boats. An effective current float or spar consists of a wooden pole 10 to 15' long, about 3" in diameter, and weighted at the bottom so that it will float in an upright position. It is important to use a float with some depth to it in order to minimize the effects of wind on the portion exposed above the water. Also a spar with a significant length under water will result in an "average" velocity determination between surface current and the current some distance below the surface. This feature will tend to overcome any large discrepancy between surface and underlying currents caused by winds blowing across or against the direction of water flow.

This simple method of current measurement can be very useful and accurate. Obviously, it will have many variations. For example, in waters that are relatively shoal, or where deep water fans out into shallow, the depth of the float may have to be greatly reduced to prevent it from fouling on the bottom and giving erroneous results. Floats with very little draft or depth can be used but the survey should be conducted during calm weather, and it should be remembered that the resulting velocity will be at the surface level only. Considerable empirical and experimental data are available for determining mean velocities: a usable rule of thumb is that the mean velocity through a cross section is about 75 per cent of the central and generally maximum surface velocity.

Floats or current spars may be used with a calibrated tagline, the float being dropped from an anchored boat with the tagline payed out and the distances and direction of drift recorded at regular intervals. The boat can be located by sextant readings to shore control or located from the shore by transit methods, using the already established preliminary control system. Another effective method for control is to use free-floating spars and cut them in at regular intervals by transits from the shore control. With this method, it is convenient to drop a number of floats over an entire area, each identified with colored pennants, etc., and obtain locations of each float at staggered intervals. This information can be plotted and the average velocities for any float are then based on the distance of drift between times noted; the direction of drift at any one location is the tangent to the curve drawn through the consecutive points.

This float method will give reliable results and is often sufficient for the preliminary survey. If a large number of current measurements over extended periods are necessary, it will be advisable to resort to one of the several types of current meters now in use. The Price Current Meter has been used for years and will accurately indicate water velocities at any desired depth, but it will not indicate directions. The Elkman Current Meter is similar to the Price Meter, will give both velocity and direction, but is recommended for relatively small velocities of 1.5 knots or less. The Coast and Geodetic Survey uses other more elaborate devices, suitable for large depths and higher velocities, such as the Roberts Radio Current Meter and the Petterson Current Meter.

Location of current recordings made by the various meters is similar to that discussed for floats. However, since the meter is operated from a boat, anchored or otherwise, generally with frequent moves to new locations, etc., location by sextant from the boat, using shore control, is generally the most convenient method.

Profile and Cross Sections

A continuous profile of the bay or river bottom along the proposed alignment of the crossing is necessary for design purposes. At pier locations, particularly larger piers, it may be advisable to completely grid the general area with soundings at say 10 to 25 feet intervals. For hydraulic embankment approaches, it is necessary to obtain cross sections at even stations or half stations to permit calculation of accurate quantities for the preliminary estimate.

Hand Sounding

The methods used and degree of accuracy of the work will vary considerably with the individual job. Certainly the simplest method of obtaining water depths is by means of hand sounding. In relatively shoal water, say up to about 10 feet, a sounding rod is very convenient, accurate and fast. A wooden or aluminum pole can readily be made to suit the job complete with calibrations to the nearest 0.1 ft. made similar to those on the typical level rod to facilitate reading and equipped with a flat round plate at the lower end to prevent penetration into soft bottom. In deeper water, a sounding line is necessary, generally consisting of a small-linked chain or similar material unaffected by the water, with calibration on the line every foot and half-foot and attached to a weight with a flat plate, if the bottom is soft. The exact features of this will, of course, vary with the depth and velocity of the water. This type of hand equipment must be used in conjunction with a tide or other water level gage, set at some convenient location to indicate the exact level of the water based on Mean Sea Level or other local datum. The procedure then is simply to obtain water depths at certain locations and correct the readings for the amount the water level is above or below say M.S.L.

Location of each hand sounding, whether by rod or sounding line, will again vary to suit the job. One convenient method is to establish range lines on shore or in the water to locate the centerline of crossing or other base line; then take the soundings from a boat located on this range line and locate each sounding or say every fifth sounding by sextant from the boat or by transit from the shore, using the preliminary control system. Location of the soundings, particularly from shore stations by transit requires a certain amount of coordination between the shore observers and the boat, including agreement on time and various signals displayed. This method of location, by maintaining the boat on a certain range line, has the obvious advantage of requiring only a single intersection or cut-in by sextant or transit to locate each sounding.

A convenient variation of this method is to maintain the boat and hence the soundings on a certain range line and control distance along this line by use of a tagline. The tagline, consisting of a calibrated light cable (1/8 inch diameter aircraft control cable is excellent), is fastened to a fixed marker on the range line and payed out from the boat by a small winch as the soundings are taken. Taglines up to about 2,000 feet can be effectively used in this manner.

If the soundings are taken at random in a general area, it becomes necessary to locate the soundings by either (a) observations by sextant from the boat, using at least three known shore control points and treating as a "three-point problem", or (b) simultaneous observations of the boat by transit from

two or three shore control points. The accuracy of any of these methods of location control will generally be something less than third order, but should be adequate for this stage of the project.

Sonic Devices

On long water crossings, particularly when a number of alignments are being studied, or when the water is fairly swift and deep, hand sounding methods can become a tremendous task. They also have very limited accuracy for the deep water with high velocity current, and it generally is advisable to resort to sonic equipment. A number of companies manufacture fathometers suitable for this type of work, which are of moderate cost, easily offset by the large savings over hand methods. These devices all work on the principle of transmitting sound waves to the bottom and relating the time elapsed between the transmission and return of the sound waves to the depth of water. The fathometer preferable for this work is the recording type, which will result in a continuous and permanent record made by a stylus on a continuous roll of paper. Location fixes or any other pertinent remarks can be made directly on the recording paper during the operation, thus giving a complete picture on the paper.

The typical fathometer consists of a control unit which records the soundings and a "fish" which transmits and receives the sound signal. The control unit for most of the older models weighs upwards to 100 pounds and requires mounting on a substantial boat; similarly, the "fish" is a torpedo-shaped device weighing about 75 pounds which must be hung overboard or, for permanent installation, a more compact transmitter and receiver can be mounted on the boat's hull. Considerable improvement has been made in this type of equipment in recent years and some manufacturers now have a unit the size of a small suitcase with a fish only 10-12 inches in length. This equipment, particularly the smaller versions, is easily transported, and can be used on fairly small craft with good results.

The accuracy of the fathometer is good, varying somewhat with bottom conditions and the weather on the surface, but with the instrument in good adjustment about 1 per cent is possible. Soft bottoms, with silt in suspension or plant growth, will result in a less distinct signal and hence a fuzzy record on the paper. Oftentimes two profile lines will result—the approximate top of the silt or growth and the firm bottom line. Such complications can readily be detected and the solution generally results with a little experimenting by comparing the fathometer operation against water depths determined by a few check hand soundings. A typical fathometer record (Fig. 6) is shown from an inspection survey of a long span bridge in Virginia.

Use of the fathometer, of course, requires knowledge of the exact elevation of the water level, the same as with hand soundings. If the water level is constant over a period, as with a lake or river, some simple surveying will provide the datum. If the project is in tidal waters, a tide gage will be necessary, as previously discussed. With the exact elevation of the water known, it becomes a simple matter to correct to M.S.L., etc., the apparent water depths shown on the fathometer recordings. Most fathometers permit an adjustment of the zero reading and with these the bottom profiles will appear correct with respect to the established datum. Fathometers are usually calibrated for standard velocities of sound in water, usually about 4800 ft. per second. If the calibration velocity does not correspond to that of the locality, corrections

for temperature, salinity and pressure may be required.

The problem of location using the fathometer is very similar to that discussed for hand soundings, but with one important difference: the fathometer, by its continuous operation, makes it convenient to operate from a boat underway. The speed of the boat can be accurately controlled and it then becomes a problem of locating the boat at certain intervals, assuming the boat's speed as constant between the fixes. The boat can again be run on a range or not and be located by sextant in the boat or from the shore by transit.

Submerged Borrow Areas

Many of our modern-day water crossings involve hydraulic dredging operations for approach embankments or causeways. Such projects present special underwater problems, including the determination of water depths and the nature of the material making up the bottom, which will be discussed later. The alignment of the embankment sections requires cross sectioning as already mentioned. Material for the embankment often will come from nearby sources underwater, all of which will require approval from the Corps of Engineers, or similar agency, in the form of a permit. Such borrow areas must be laid out generally in a grid form with several ranges and soundings obtained on anywhere from 50 to 500 feet centers, depending on the problem. These borrow areas will frequently be in relatively shoal water and simple markers can be located in the water and the soundings taken by hand or fathometer methods with the location controlled as previously discussed. Borrow areas may take the form of new boat or ship channels to be dredged adjacent to the new facility. The treatment in such cases will be similar, although the distances may become very large and use of fathometer methods may be imperative.

3. Geological and Foundation Surveys

General

The subsurface geological and foundation survey for a bridge project often is the most important portion of the preliminary stage. Foundations for small, "dry land" type of turnpike bridges oftentimes are relatively routine and may require only a few shallow subsurface borings. On the other hand, modern bridges crossing large bodies of water often become involved with unusual and changing subsurface foundation conditions and require considerable planning and careful field investigation. As bridge building techniques are gradually improved, we are attempting construction of water crossings which, a few years ago, seemed impossible. In many cases, it was the unusual foundation conditions which made some of these bridge sites impractical until recently.

The need for accurate subsurface foundation information from a design standpoint is, of course, quite obvious. The stability of large bridge structures is not generally a routine problem. There are many existing structures which are undergoing gradual settlements or lateral movements, which conditions probably could have been overcome by more thorough foundation exploration.

Economy of construction cost is another important reason for thorough subsurface investigations. Comprehensive geologic surveys may indicate

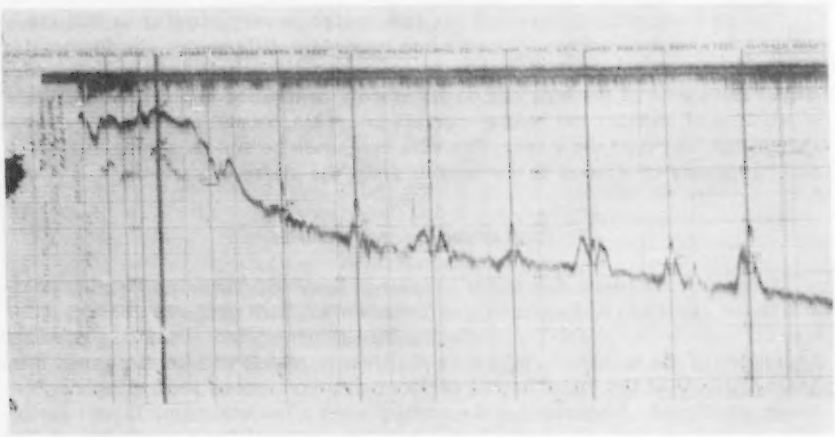
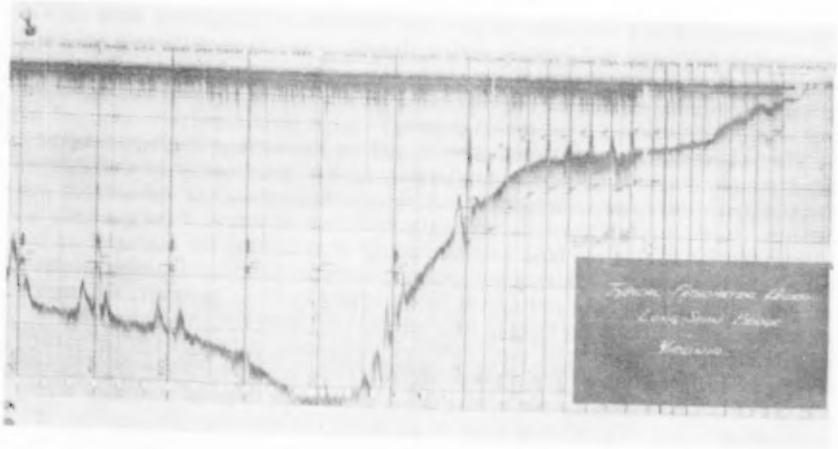


Fig. 6. Typical Fathometer Record Long Span Bridge, Virginia.

more economical locations for the bridge crossing and its individual piers, thus warranting a relocation from the sites selected on the basis of other considerations. Furthermore, the actual design of the bridge structures based on incomplete surveys may lead to excessive final construction costs. In effect, the engineer is passing on to the contractor the uncertainties of the foundation conditions, which uncertainties are bound to affect the contractor's bid prices for the work and invariably result in costly extras during construction.

The geological surveys should first include an exhaustive review of all available information on the site of the work. The U. S. Geological Survey and many states and cities publish information on local geologic conditions, much of which provides excellent guidance for the planning of the foundation explorations. In addition, the U. S. Geological Survey compiles indices to geologic maps and reports of Federal and State agencies, Universities and professional societies. Aerial photographs will often be helpful at this stage. Also the details and behavior of the foundations of existing structures in the immediate vicinity will be important both in planning the explorations and in completing the structural design later. With this general background information, the foundation explorations should be carefully planned utilizing the combined efforts of the structural engineer, the soils mechanics specialist and perhaps the geologist on the more comprehensive explorations.

There are many techniques available to the bridge engineer for carrying out the foundation explorations, the details of which are beyond the scope of this Manual. This writing is intended only to serve as a general guide and the reader should refer to such publications as "Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes", an A.S.C.E. Report prepared by M. Juul Hvorslev. Subsurface borings and probings are the most common approach. Test or index piles may be driven and loaded. Test pits may be excavated and loaded for shallow explorations. Electrical resistivity and seismic methods may be used and in some instances aerial photo interpretation.



Subsurface Borings

The most common and generally the most effective method for exploring the subsurface conditions for the bridge project is by means of a boring program. For the small "dry land" turnpike-type of bridge structure, such a program will often consist of taking about two or three borings for each bridge pier and abutment, the hole depths varying with the problem. When the foundation conditions are expected to be sand and gravel, glacial deposits, etc., the holes may be of the order of 25 to 35 feet in depth, with a penetration of 5 to 10 feet into rock if encountered depending on the soundness of the rock. If boulders or weathered rock are encountered, it is generally necessary to core through and still get 5 to 10 feet penetration in sound bed rock. When softer materials are encountered, the depths will of course be much greater.

For the longer water-crossing type of bridge, the boring program will generally consist of one boring for each of the smaller piers and two or more borings for the main piers. For bridges including pile bent construction for approaches, one boring every 200 to 500 feet is common, depending on how variable the bottom conditions are. The depths of these holes will again vary with the design loading on the piers and with local conditions. The specifications for the boring contract should contain an estimate of hole depths based on preliminary design considerations and knowledge of general subsurface conditions. However, the final hole depths in each case should be dependent upon actual findings and judgment in the field as the boring work progresses. For the typical pile bent type of construction, hole depths below bay or river bottom may vary from about 50 feet in firm bottom to over 100 feet in soft or poor bottom; if rock is encountered, 5 to 10 feet penetration into sound rock is generally sufficient. For large bridge piers, either on piles or on spread footings, it is rather difficult to generalize. In such cases, it is not only important to determine accurately the overburden materials and the rock formations, if they exist, expected to support the pier, but also to probe to depths far in excess of the bottom elevations of the pile tips or spread footings. To this end, it is often advisable to treat the first boring for a large pier as exploratory and generally decrease the depths of succeeding holes in the same

area if the log of the first hole is favorable. This is particularly true where rock formations are encountered that are variable and stratified, such as with alternating hard and soft layers, and in limestone which may contain solution cavities. Such a procedure will preclude the possibility of founding large piers over voids or poor supporting material occurring at extreme depths below harder strata of soil or rock.

There are many general methods for making subsurface borings ranging from simple displacement borings yielding limited information to undisturbed sample and rotary core borings, resulting in complete logs of subsurface conditions. Most borings involve combinations of two or more of the general techniques for boring the hole and displacing or removing the material as the bore hole is advanced. Boring equipment generally includes a casing necessary to stabilize the hole and driven into the soil by drop hammer, although under some conditions the casing may not be required; drilling, sampling and/or clean-out equipment; power driven equipment at the ground or water level generally utilizing an A-frame with which to manipulate the drop hammer and the drill and sampling tools; and pump equipment in some methods for circulating water or a drilling fluid to facilitate the drilling and removal of material from the bore hole. A brief summary of the more commonly used methods for advancing a bore hole follows, but the reader is again referred to such manuals as that edited by Mr. M. J. Hvorslev for complete details.

Displacement Boring

This method generally consists of forcing a closed sampler into the soil without the use of a casing, the hole being generally advanced by continuous use of the sampler. This method is obviously limited by the type of soil and the ground-water because of the lack of casing. Major changes of soil can be detected with fair accuracy and disturbed samples of the soil are obtained for study. The method is best suited for general reconnaissance and exploration of shallow relatively simple foundation conditions.

Wash Boring

This method involves the use of a hollow drill rod with bit forced into the soil by a chopping and twisting action, with the aid of the jet water. Casing is required for this method in soft or cohesionless soils but may be omitted in some cohesive soils. General character of the soil is determined by the behavior of the drill tool and examination of the wash water containing material from the bore hole. Approximate elevations of major soil changes can be obtained, also the elevation of boulders or rock if encountered. This method is suited for general reconnaissance and to supplement other more accurate methods. Results can be misleading and should be used with caution.

Auger Boring

The hole is advanced in this method by forcing and rotating a soil auger into the soil and retracting the auger at intervals with its load of soil. The auger may be hand or power operated and, since it is generally used in an open hole, its effectiveness and possible depth will depend considerably on the type of soil and the elevation of the ground water table. The method is very useful for relatively shallow explorations and, although the soil sample is disturbed, it does enable a positive identification of the soil.

Rotary Drilling

The bore hole in this method is advanced by means of a rotating drill tool using a circulating water or drilling fluid for facilitating the drilling and removing the cuttings. A casing is generally used, although it may be omitted after the hole is started and the nature of the soil is such as to make possible an uncased or freestanding hole. The general character of the soil is determined by the progress and action of the drilling tool and by the cuttings in the water or drilling fluid. No intact sample or core is obtained. This method has limited use for bridge exploratory work and its results must be interpreted with caution.

Drive Sampling

This is a broad category referring to the general method of advancing a bore hole with or without a casing by means of a special soil sampling device forced into the soil by hammering, jacking or pushing. The open drive samplers include those with solid or split barrels, thick or thin walls and those with liners. The piston sampler has several variations including the retracted, free and stationary piston types. Each has its advantages and disadvantages, yielding samples with varying degrees of disturbance and the reader should consult appropriate references for details. This general method is very useful for the bridge subsurface exploration for borings in materials other than rock.

Core Drill Borings

This category includes the method of advancing a bore hole in certain soils or rock by means of a rotary drill with bit and core barrel, using a circulating drilling fluid, and permitting recovery of a sample or core of the soil or rock. Several effective bits with core barrels are in common use, but the diamond bit with single or double tube core barrel is perhaps the most useful for bridge exploration in rock. The percussion core boring is another method in this category but it has a number of disadvantages for bridge exploratory work.

Probings and Soundings

This method generally consists of forcing a rod into the soil and noting the resistance to penetration, the elevation of apparent boulders or rock stopping further penetration and the resistance to withdrawal of the rod. There are many variations to the rod and methods of forcing the rod into the soil from hand driving with sledge hammer to driving and/or rotating the rod by power means. Also a wash probing is at times helpful using a hollow rod with water under pressure as a jet to penetrate the soil. In this case, observation of the wash water will yield approximate information on the soil conditions but such information can be very unreliable and should be treated with caution. In general, this method is suitable for only the very preliminary explorations, for the relatively shallow and simple foundation problem. Profiles of soil and rock strata from this general method can be helpful and supplement the more accurate exploratory methods, but the results can often be misleading and should be carefully analyzed and interpreted.

Index Piles and Bearing Load Tests

The subsurface boring program may or may not give sufficient information in itself to enable final design of the bridge piers. There are many factors to be considered by the structural engineer and soils mechanic depending on the structure and the location and to generalize is next to impossible. Much of this is outside the scope of this Manual but it is appropriate to review the problem in general at this stage.

The results of the boring exploration for the bridge project will probably indicate the relative feasibility for spread footings, pile foundations, or some type of caisson construction. If a spread footing is indicated for a certain pier, the boring information often will be adequate for design. If some doubt exists, it might be advisable, in the case of a dry-land pier, to dig a test pit, perform a bearing load test and laboratory tests on undisturbed soil samples; for the water pier, a bearing load test is impractical, but laboratory tests on undisturbed samples might be required. If some type of caisson construction is indicated, the subsurface borings, perhaps with some laboratory tests of undisturbed samples, will probably be sufficient for design. However, when the pier foundation is to be on piles, it might be advisable to supplement the boring results with index or test piles and possibly load tests.

The driving and loading of index piles is a relatively costly operation compared to subsurface borings. Decision to perform the work often will come after completion of the borings. Also the nature of index piles is such that heavy construction equipment will be required particularly for a water crossing. If the job is large enough, it may be feasible to handle the work by a separate contract as part of the preliminary stage before the start of actual construction. If index piles are desired primarily to confirm conclusions reached from the borings, it may be possible to complete the design and arrange that the index piles be driven and perhaps loaded as the first operation of the first construction contract. This is a fairly common and effective arrangement, although it does introduce more risk and the possibility that planned pile lengths may be changed at a later date. In view of all this, the need for the index pile and the complications that may result should be given careful consideration.

The index piles should be the same type pile contemplated for the final structure to obtain the maximum benefit for design purposes. This is generally possible within reason. It is generally known after the borings what the type of pile will be, such as steel "H", hollow metal, reinforced concrete or timber. If prestressed concrete square or cylindrical piles are planned, obviously regular reinforced concrete piles with the same outside dimensions will serve for the index piles.

The index piles may or may not be driven in final location to be incorporated in the structure later. If the pile driving is being done during the preliminary stage, probably the survey control is not sufficient to give precise location; also the driving may be accomplished with equipment and rigs hastily set up for the driving of only a few piles, and the result often is poor location and inferior driving control. Under such conditions, it is best not to try to incorporate the index piles into the structure, but rather make certain they will be clear of everything. Sometimes, when the index piles are part of the first construction contract, these disadvantages may not exist and the index piles may be satisfactorily used later as permanent piles. Further, the index piles should be located close to representative borings so that the two can be

correlated with one another: in this manner the tip elevations of the index piles, where hard driving or anything erratic occurred, should be found to correspond to certain strata in the boring logs.

The actual driving of the index pile is straightforward, differing only from the driving of piles in general by virtue of the fact that it is exploratory and hence every possible observation and measurement should be recorded. A load bearing test applied to an index pile is generally a simple static loading proposition the details of which will not be discussed here. The reader should consult such publications as "Pile Foundations", by R. D. Chellis (published by the McGraw Hill Book Co.) for complete details.

Test Pits and Bearing Load Tests

Excavation of a test pit, by hand or power equipment, with or without a bearing load test, often affords an effective means of determining subsoil conditions. However, this method is limited to the dry land piers and to relatively shallow depths depending on the type of soil and the elevation of ground water. An open excavation 6 to 10 feet in depth will generally be the maximum in most soil conditions; if the hole is sheathed, greater depths are possible, but the cost will become rather high. For the average to large bridge project where borings are planned, it is generally more feasible and economical to use the borings throughout, possibly supplemented by test piles as previously discussed. If an unusual shallow condition is encountered at the location of some of the dry-land piers, the test pit can then be excavated to provide additional information.

The general approach to a soil bearing load test is similar to that for the pile bearing load test, except that a bearing plate supported by the soil or rock replaces the test pile. There are, however, many variations in the details of making the test, and applicable publications, including building codes, should be consulted either for compliance or guidance as the case may be.

Geophysical Methods

Geophysical methods used for subsurface exploration consist essentially in interpreting changes in character of soil and rock formations from measurements made on the gravitational, magnetic, electric and elastic wave propagation properties of the earth. These methods have long been used in prospecting for oil and minerals but are also becoming increasingly useful to the civil engineer.

The seismic method is probably the most useful for geologic surveys for the bridge project. It is based on the principle that the velocity of propagation of a shock wave in soil and rock formations varies with the modulus of elasticity and density of the material. The wave or impulse is generally produced by exploding a small charge of dynamite on the ground surface or in a shallow bore hole. The time required for the impuise to reach certain other points along a line on the ground surface is measured from an oscillograph with the aid of detectors or seismometers; the detectors convert the elastic wave energy into electrical energy which is fed to the oscillograph. There are two distinctly different methods, one based on the refraction and the other on the reflection properties of energy waves through the soil and rock. The refraction method may be used for relatively shallow exploration; whereas, until

recently, the reflection method was limited to subsurface exploration to greater depths, over about 2,000 feet, and hence best suited for prospecting work. However, recent developments have made reflection equipment available for depths as shallow as 50 feet.

In general, the seismic method is better suited to the preliminary geologic surveys for the bridge project although it may under some circumstances, be useful for the detailed explorations by supplementing data obtained by borings and other methods. The seismic method has definite limitations. It can be used only when the wave velocity increases with the depth of soil and rock formations. The method requires knowledge of certain physical properties of the soil which can best be obtained from measurements of samples from subsurface index borings. When the properties of the soil overburden are variable and the rock variable and badly weathered, the accuracy of the seismic method becomes limited and the number of borings necessary for indices must be increased to the point where it becomes more economical and expedient to resort to sole use of the orthodox borings at each pier. The seismic method is generally most useful for the preliminary exploration of a long water crossing when the final alignment is to be determined from a number of alternate locations. Under such circumstances, the seismic method will generally result in an economical, rapid and sufficiently accurate determination of subsurface conditions to permit definition of alignment.

Electrical methods of subsurface exploration are based on the measurement of differences in electrical conductivity or resistivity of soils and rocks from which interpretations can be made. These methods are similar in some regards to the seismic methods and require subsurface borings for reliable evaluation or verification. The electrical resistivity method is quite commonly used in civil engineering and is practical for the land piers but not for those in water. It can be used for subsurface investigations to depths of several hundred feet and will result in a rapid, economical and fairly accurate determination of soil overburden and the presence of rock when the subsurface conditions are relatively uniform. On the other extreme, complicated and variable subsurface conditions may require so much supplemental information from index borings as to render the resistivity method impractical, the solution then being to take borings throughout. This method can be very useful for providing such information as the extent of certain materials planned for borrow after the source has been located by auger or dry sample borings. Reference is made to the U. S. Bureau of Standards Bulletin No. 258 by Mr. F. Werner.

The sonic method used in hydrographic surveying to determine depths to water bottom is also being developed as a tool for interpreting geological conditions below the water bottom. In a few test areas, the bedrock profile beneath the bottom sediments has been outlined. Additional sound traces from layers within the bottom sediments may prove useful in interpreting the geology of underwater areas where more than one type of unconsolidated or poorly consolidated material overlies bedrock.

Aerial Photo Interpretations

This method will only be mentioned in passing since it is much more useful in connection with highway rather than bridge engineering. Essentially, this technique concerns the use of aerial photographs coordinated with a surface

survey of geological conditions to "interpret" the subsurface conditions. The process in some areas has proved very accurate, but obviously has limitations. If aerial photo interpretation is planned for the highway approaches, it may also be of some assistance in designing the dry-land approaches to the bridge. For the water portion of the crossing, this method is of little value other than to give general ideas of shoal water, bottom growth, channels, etc. The method may be useful for reconnaissance and general planning and to supplement data obtained by other means.

Laboratory Soil Testing

The subsurface exploration techniques briefly discussed are essentially performed in the field. For the small turnpike type of bridge structure, auger borings or one or two shallow cased borings with samples may suffice. The long water crossing may entail all of the more elaborate borings, index piles with load tests, test pits with load tests, and even some seismic work to fill in missing information. The results of all this—the boring logs and samples, the pile driving logs and load tests, etc.—will often constitute sufficient information for the detailed design of the structure. For the large and complicated project, however, additional laboratory testing of soil and rock samples may be indicated if a review of all the field information points to any unusual conditions.

Physical and chemical analyses of soil and rock samples may be useful to supplement the visual classifications by the boring inspectors. Sometimes the weathering qualities of a rock or the acid condition of a soil may require special design considerations. The A.S.T.M. Standards should be consulted in connection with such physical property tests as mechanical analysis (grain size), unit weight, maximum density and optimum moisture, liquid and plastic limits, etc.

Shear and consolidation tests of soil samples may be necessary to supplement boring and index pile data. For example, the driving record of the dry spoon sampling operation may not be conclusive and fail to indicate a good build-up in soil bearing capacity, the index pile driving log may not appear consistent with the boring log or visual observation of the soil samples may not give positive identity of classifications and characteristics. Under such circumstances, it would be important to perform additional shear and consolidation tests using the undisturbed samples obtained from the boring work. Again, the A.S.T.M. Standards and the soils engineer should be consulted for guidance.

Borrow Material Sampling

The general discussion of subsurface exploration and testing has been devoted to the bridge site itself—to the individual pier locations and embankment approaches. However, many long bridge crossings involve large quantities of fill materials for approaches and causeway sections in the water, and the exploration necessary to obtain the borrow material is often a problem to be considered.

This borrow exploration is similar many times to that required for the highway project and hence the comments made in other Chapters in this regard are partially applicable. The borrow may come from either land or

water areas, and in both cases should be explored to some extent. On land, a few simple shallow borings will generally suffice and the samples studied visually or analyzed in a laboratory to make certain of the suitability of the borrow. If there is a question of quantity of borrow available, the source should be further investigated for extent by additional borings, hand probings, or an electrical resistivity method. When the borrow is to come from a submerged area, the problem is similar and suitability and extent can generally be determined by borings, hand probings, or at times by samples obtained directly from the bay or river bottom. Obviously, if the bottom shows silty alluvial deposits such a bottom sample would be unreliable. Submerged borrow areas are excavated most frequently by means of a hydraulic dredge or a suction hopper dredge. This does not alter the exploration problem, but the handling of the material by hydraulic means, both in picking up and placing, results in considerable loss in fine material, which should, of course, be considered when passing judgment on the suitability of the borrow.

Location of Test Sites

The preliminary survey control, established during this stage of the work and discussed under "Surface Surveys", will afford the means for locating the subsurface exploration operations both horizontally and vertically. Horizontal control will be based on the preliminary triangulation network in much the same manner as for the soundings and current measurements taken during the "Hydrographic Surveys". The existing and newly established preliminary bench marks will provide the necessary vertical control.

The control problem for the bridge subsurface exploration will generally consist of spotting borings, test piles or pits, seismic or resistivity lines on land or in the water, at the locations of the proposed piers and approach embankments as the case may be. For the land piers, this obviously becomes a matter of simple surveying establishing a station location along the proposed longitudinal centerline of the bridge and an elevation to work with from a convenient bench mark. The water piers on the other hand often present a much more difficult location problem, particularly when water distances are great and considerable resourcefulness will be necessary along with the engineering approach. The actual boring work and driving of test piles will generally be done from small barges and floating pile driving rigs, often hastily assembled and of the "fair weather" variety. For the large project with very deep water, it may be necessary to do the boring work from fixed platforms which will facilitate the control problem. Accurate location of these in rough open water with only a preliminary control system can be troublesome.

Horizontal Control

Locating the test sites on land presents no problem. On the water, the simplest and most direct method of spotting borings or test piles at pier locations is to establish the longitudinal bridge centerline or a convenient offset line by means of a visible range, say with two widely separated targets on shore; navigate the floating equipment along this range and locate its position by instrument observations from control points on shore. This is generally referred to as an intersection method, wherein calculated intersection angles are laid out by theodolite or transit occupying control points in the net, the angles being measured or turned between other control points in the net and targets on the floating equipment.

This method obviously has many variations which will be apparent to suit the problem and the control system. Oftentimes with long water distances and rough weather, it becomes necessary to locate a floating rig approximately and proceed with the boring or pile driving; then later under better conditions triangulate to the rig from two or more shore points, thus arriving at a calculated location of the rig which may be somewhat off exact centerline and pier location. The same general approach is possible using sextant observations from the floating equipment, observing targets on shore control points. If the rig is on the longitudinal bridge centerline or a known offset line, one sextant angle will fix location. If the rig is off centerline or at some random location, sextant observations on three known control points will be necessary and the location solved as a "three-point problem". The circular chart solution of the "three-point problem" is very fast and accurate and is ideally suited for this and similar problems.

Still another variation is to use a calibrated tagline as discussed under "Hydrographic Surveys". The rig may be located along a range line by measuring tagline distances from some fixed point on the range or centerline. Also, when the working rig is a fairly stable barge or boat of some sort, it may be convenient to set up a surveying transit on the deck of the rig and locate a position along the range line by the principle of stadia. Both of these methods are particularly effective when driving test piles, when, for example, the first pile in an area has been located by intersection or triangulation. Then, subsequent piles can be located from this first pile by means of either attaching a tagline to it and measuring along the range line, or marking a certain vertical measurement on the pile which can be intercepted between the stadia hairs of the transit mounted on the floating rig.

The sampling of borrow areas may also present location problems, but the approach is similar to that for the exploratory work at piers. Borrow areas on land present no real problems. Submerged borrow areas are generally controlled as discussed under "Hydrographic Surveys". The use of the sextant with the "three-point problem" solution is particularly adapted to this type of location.

Vertical Control

Elevations to work from are necessary for all methods of subsurface exploration. Each boring will require a ground elevation or elevation of some fixed point as top of casing from which to determine elevations of samples, strata changes, etc. Similarly, the index pile will require a ground elevation or elevation of some fixed point on which to base the driving log and load test. Exploration by test pit and geophysical methods also require a few elevations, principally of the ground surface.

Vertical control for the test sites on land can be handled by simple leveling methods using the bench marks established as discussed under "Surface Surveys". The only special surveying problems may occur in connection with the pile load tests and the soil bearing tests, which require accurate measurements of settlement and rebound. Details of this will depend on the methods used to apply the load tests. Generally such measurements can readily be made by means of a surveying level observing fixed points near the test and tell-tale points on the load test, using a stretched piece of piano wire as a gage from which to make measurements or with the aid of an extensometer measuring relative movements between a fixed point and the moving load test.

For the test sites located on the water, the problem can be more troublesome particularly for the long crossing and deep water. The general methods discussed under "Vertical Control - Surface Surveys" can be useful here since the problem is similar to carrying level control across a body of water. Use of reciprocal leveling, regular fore and backsight leveling with corrections for the long unbalanced sights and water or tide gages all are useful in transferring an elevation from a bench mark on shore to the test site.

At the start of the subsurface boring, the bay or river bottom elevation at the site of the test can be obtained by sounding as discussed under "Hydrographic Surveys". This bottom elevation can be transferred to the water surface and the top of casing, again by sounding line, as the boring is advanced. Once the driving has stopped on the casing, as when the casing has reached rock, the top of casing becomes a fixed point and the level control based on the bottom elevation can be checked by leveling or water gage methods from the shore bench marks. Of course, if the boring work is being done from a fixed platform, the more precise level control can be extended to the platform before the boring is started.

Vertical control for the test pile is similar to that for the boring. Generally the bottom elevation can be used tentatively to permit driving of the pile. Once the pile butt has become fixed, a more refined grade can be extended from the shore control. The test loading of a pile generally requires the construction of some sort of platform, which will provide a working base for establishing a grade and the measurement of settlement of the pile during the test can be obtained as discussed for the land piers.

Respectfully submitted,

Oliver R. Bosso
R. H. Dodds
R. A. Haber
Peter A. Hakman
A. A. Katterhenry
John G. McEntyre
C. A. Rothrock
L. R. Schureman
Milton O. Schmidt, Chairman

Committee on Highway and Bridge Surveys of the
Surveying and Mapping Division.

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CHARTS FOR THE AIR FORCE[a]

Richard W. Philbrick,[1]
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ABSTRACT

Charts for the United States Air Force are published by the Aeronautical Chart and Information Center. About 2500 persons apply the latest photogrammetric and cartographic techniques using carefully researched data to keep aeronautical information current. They reproduce and distribute, throughout the world, about one hundred million charts a year.

During the past several years, the subject of charts has become more and more interesting to civil engineers, particularly those engaged in surveying and mapping.

The story of chart making (or cartography) goes back a long way. Perhaps even primitive peoples used sticks to make drawings on the ground depicting the location of roads, streams, and villages. One of these simple topographic maps, drawn on a clay tablet about 2500 B.C. is on display today in a Harvard Museum. However, it is considered that chart making seriously began when man took to the sea. Nearly 3,000 years ago when the Phoenicians began to build sturdy craft from the cedars of Lebanon and to extend their commerce throughout the Mediterranean, they found it necessary to devise some sort of a chart that would help them find their way, with stars as checkpoints, from one port to another. These early charts were crude drawings, showing in a very general way, the shore line and the approximate locations of harbors, towns, shoals, and caravan routes. They covered limited areas since man at that time knew so little about the geography of the earth.

During the heyday of the Greek scholars and mathematicians, when man began to seek some of the answers to the riddles of the universe, many

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1. Col., USAF, Commander of the Iceland Air Defense Force, formerly Commander USAF Aeronautical Chart and Information Center.

scientific experiments were conducted. Eratosthenes, in the second century before Christ, is considered to have founded scientific geography. He reasoned that the earth was round and calculated the approximate circumference of the globe. It is believed that he made the first map of the world. Hipparchus improved the maps of Eratosthenes by stabilizing the lines of longitude and latitude.

During that time many charts were made that were reasonably good representations of the Mediterranean world. They showed its relationship to the imaginary continents and oceans that those early chart makers believed were part of the vast void, which to them constituted the remainder of the earth.

The conquests of the Caesars, during the early period of the Roman era, just before and after the time of Christ, resulted in an increase of geographic knowledge about Europe, parts of Africa and Asia. This knowledge, together with improved drawing techniques, resulted in charts which were much better than those of earlier periods. The Romans, however, never produced a first class geographer or cartographer. Promotion of these sciences during the early Roman period, fell to Claudius Ptolemy and other Greek scholars living in Alexandria.

For a thousand years, between the fourth and fourteenth centuries, A. D., when there was very little progress in any scientific field, cartography marked time too.

Interest in geography and exploration flared up due to the restless and adventurous spirit of the century preceding the discovery of America. Several schools established courses in navigation, geography, astronomy, and other subjects which helped advance cartographic knowledge. Better charts were made of known areas of the world. More accurate speculation was made of what was thought to exist beyond the charted areas. The stage was set for the voyages of Columbus, Magellan and many others; for the amazing era of discovery that followed. Learned men in the cities of Europe began calculating the size and shape of the earth. They resurrected some of the maps and charts made centuries before and began making new ones. They began to place continents, oceans, seas, in relatively accurate positions on maps of the world; cartography was on its way.

Once the early cartographers realized that the earth was round they were confronted by a problem which still plagues cartographers today: the problem of representing the curved surface of the earth on a flat piece of paper. About the middle of the sixteenth century an ingenious Dutchman named Gerardus Mercator (realizing that the only true chart or map would have to be made in the form of a globe), devised a map projection which bears his name. He wrapped a sheet of paper around the best globe available and transferred the land areas from the globe to the sheet of paper, enlarging the land areas in each direction as he approached the north and south poles. The Mercator Chart (or map) proved to be of tremendous advantage in navigation because it showed true direction. However, it had a great disadvantage, in that accurate distances could not be measured except in the vicinity of the equator. The scale in extreme northern and southern parts of the world was greatly enlarged. Remember the geography class maps that showed Greenland to be larger that South America? It actually is only about one tenth the size. Although the Mercator map represented a milestone in cartography and has many applications today, it has been a task of cartographers ever since to develope new or modified map projections that will come closer to what is needed in particular charts or maps according to scale and intended use.

Many of these projections represent compromises in various existing projections in order that the requirements for multi-use may be fulfilled as nearly as possible.

During the sixteenth through the nineteenth centuries, as time went on, as sea commerce grew, as adventurers pushed westward, and sometimes eastward, charts just had to get better and better. Methods of astronomic observation were devised. They made it possible to more accurately locate ground features with respect to the lines of latitude and longitude. Explorers and surveyors pushed farther into unknown areas and brought back more information about the topography of the earth. Improved surveying instruments and methods contributed greatly to chart making progress. Cartographers worked toward improvement in chart portrayal and standardization of symbols as new material became available.

By the beginning of the twentieth century most of the world was mapped or charted in some manner and certain limited areas mapped, quite accurately, at large scale. Chart making had, after fashion, kept pace with civilization. The twentieth century, however, was destined to be unique in the history of man. Scientific achievement began to go forward at an accelerated pace.

Out of the tests on the sand dunes of Kitty Hawk the airplane was hatched in 1903. It grew to become an important factor in civilization and synonymous with National survival.

Early development of aviation was slow. It took a long time to get it out of the embryo stage. It took a longer time for most people to realize that it would become one of the principal modes of transportation. By 1917 it had not reached a stage where it could be considered a major weapon of war. Near the end of World War I, it was used effectively in the execution of short range bombing raids in France and for observation purposes. Even so, few charting materials and navigational aids were required, since most aerial activity involved short flights without the elaborate air navigational equipment and systems that are used now.

After World War I, there was a stimulated interest in aviation for peacetime purposes and, to a limited degree, for military purposes. But it was not until World War II that the airplane really came into its own. It took World War II to demonstrate that the airplane was a major instrument of war and a major deterrent to aggression.

It is significant, yet lamentable, that so much of the technological advancement of civilization has occurred as a result of military necessity. Every major war has brought with it a demand for maximum effort in pushing scientific developments forward. This has been true of the airplane; and it is also true of cartography.

Even at the beginning of World War II there was very little military aviation activity that required any special charting materials beyond those available in the form of hydrographic charts, military maps and other general purpose maps. Prior to that time there was a small Map Section in the Army Air Corps whose task it was to collect maps and other material considered useful for air navigation purposes and distribute it to the Air Corps units.

However, during the early part of the war there was such an amazing advance in the field of engineering and particularly in the technological development in aviation regarding speed, manueverability, range, altitudes, and electronic aids to navigation, that a requirement suddenly developed for a brand new type of cartographic product—the aeronautical chart.

In 1941, the Map Section of the Information Division (later known as the Map Chart Division), Army Air Corps, planned the preparation of several

basic series of aeronautical charts in various areas of the world. Arrangements were made with several government agencies including the U. S. Coast and Geodetic Survey, Army Corps of Engineers, and a number of commercial organizations to compile and publish these series of charts. They included the World Aeronautical Charts, scale 1:1,000,000, covering the land area of the earth (except for the interior of Antartica); the World Long Range Navigation Charts, scale 1:3,000,000, which covered the world; and the World Planning Chart, scale 1:5,000,000; also, Pilotage Charts, scale 1:500,000, and Approach Charts, scale 1:250,000 covering selected areas; targets charts of various scales; and certain aeronautical information publications. The Aeronautical Chart Service was activated in 1943 with its Aeronautical Chart Plant established in St. Louis. During the remainder of World War II this organization produced the charts that were needed by the Air Force.

Immediately after World War II, there was a curtailment of military activity and a corresponding lag in the advancement of aeronautical charting.

By 1948 interest in military preparedness had revived. The Air Force had become a separate arm of national defense. Emphasis was placed upon the development of a powerful Air Force. Strategic air offense was given special attention. Research and Development was expanded to create new and effective air weapons. This was the concept for maintenance of United States air supremacy.

The rapid surge of aviation was causing the world to shrink. Distances which afforded some nations protection against aggression no longer existed. Oceans and seas were reduced to the status of millponds. Almost any spot on earth could be reached in less than 24 hours from a local airport.

This rapid growth in aviation also presented a challenge to producers of graphic materials for use by the Air Force in navigation and other air activity. Increased speeds, ranges, altitudes, manueverability of new aircraft, the introduction of many new electronic aids to navigation, and the development of highly complex weapons systems created the need for graphic materials of many new types to support modern aviation. To meet this challenge the Air Force increased the size of the Aeronautical Chart Service five fold. New programs were initiated to provide new materials such as air objective graphics of potential military targets throughout the world. Revamping of existing aeronautical charts began. Methods were overhauled for compiling and portraying information on the charts.

In 1950 the Korean War broke out. This war created the need for new, specialized types of charts in the Far East. It also served as a proving ground for testing the effectiveness of the new charts for use with new military weapons, especially jet aircraft, under combat conditions. Production and distribution problems were tested which would be especially valuable in all-out-war.

While the Korean War was still going on, the name of the organization was changed to the Aeronautical Chart and Information Center; the headquarters was located in St. Louis, Missouri.

The Center, commonly known as ACIC is, organizationally, a component of the Air Photographic and Charting Service. Its headquarters is located in Orlando, Florida. Other components of this Service are responsible for the accomplishment of aerial photography, airborne electronic surveying for the procurement of geodetic control data, and the preparation of Air Force motion pictures. It is one of the service organizations assigned to the Military Air Transport Service.

The Aeronautical Chart and Information Center is charged with the responsibility for providing the Air Force with aeronautical charts, graphic air target materials, aeronautical information publications, maps, terrain models, evaluated intelligence on air facilities, and related cartographic services. The full scope of this responsibility includes developing Air Force cartographic requirements, planning production programs, collecting and evaluating source materials, compiling, reproducing and distributing the various cartographic items; the collection, cataloguing, storage and distribution of foreign or domestic charts or special maps produced by other agencies; the maintenance of adequate files of world-wide aeronautical information for dissemination through the media of information publications, and the establishment and maintenance of offices in overseas theaters. It also maintains a central file of all Air Force aerial and still photography and an operational print file of selected aerial photographs for common use by the Department of Defense and other authorized agencies; provides photographic laboratory services to Department of Defense agencies; and provides for the sale of unclassified aerial photography to government and commercial organizations, institutions, and private citizens as prescribed by law. A training facility is also operated for technical training of field unit Air Force personnel engaged in cartographic work. Production of aeronautical charts and aeronautical information publications covering the United States and its possessions where military and civil requirements are parallel is the responsibility of the U. S. Coast and Geodetic Survey. The Center produces charts and publications of domestic areas to fulfill requirements that are solely military in nature.

This is accomplished by an organizational structure of staff offices including Directorates of Personnel, Materiel, and Operations. Directly concerned with primary mission accomplishment, Operations investigates technical requirements to be fulfilled for weapons systems; develops cartographic requirement for supporting weapons systems and Air Force activity in general; designs the charting material required; develops and implements approved cartographic programs. This is accomplished through the Production-Distribution Plant. About 2500 persons are employed to compile, reproduce, and distribute charting materials. The latest photogrammetric and cartographic techniques use data that has been carefully researched. Aeronautical information is kept up-to-date; giant litho presses reproduce the millions of charts distributed throughout the world.

Collection and dissemination of aeronautical information is achieved through a detachment of the Center in Washington, D. C.; the 1357th Aeronautical Information Squadron in Germany with its detachments in England, France, and Spain; the 1358th Aeronautical Information Squadron in Japan with its detachments in Hawaii and Guam; along with detachments in Alaska and the Canal Zone.

Three broad categories characterize the products of ACIC: Standard Aeronautical Charts range in scale from 1:250,000 to 1:5,000,000 are used in all types of flying, operational planning, staff planning, flight training, air-ground support and as substitutes for target charts; Air Objectives materials, scale 1:10,000 to 1:500,000, target data sheets, and target information in text form, are used to support targeting programs and for intelligence purposes; Aeronautical Information Publications, which generally consist of combined textural and graphic materials provide all elements of the Air Force with aeronautical information and aids to navigation.

These categories divide into some 80 series. Each designed for a specific

purpose. The cartographic workhorse of the Air Force is the World Aeronautical Chart—commonly known as the WAC. This series consists of 958 charts and provides world coverage of land areas at a convenient size and scale suitable for general air navigation, including pilotage (navigation by means of check points on the ground), radio, radar, celestial navigation and dead reckoning. The WAC is used jointly by all defense agencies and was used as a model for, which makes it almost identical with, the 1:1,000,000 scale chart sponsored by the International Civil Aviation Organization.

Other important charts series are Pilotage, Aeronautical Approach, Jet Navigation, Planning, Gnomonic Tracking, Loran and Consol, Weather Plotting, Target charts and aerial mosaics.

New and current weapons systems have increased the requirement for accurate geographic positioning of ground features.

The very nature of powered flight makes it necessary to rigidly control the movement of all aircraft at all times. Rules and regulations, on a national and international basis have to be established. So that all pilots can conform with these rules, various "aids to navigation" are published and maintained on a current basis.

Detailed description of each chart series would become very extensive, however, there are a few unique items under development, which may be of special interest to the reader.

One of them is the video mapping plate which consists of a film negative mounted on a glass disc, ten inches in diameter and designed to cover an area of 200 miles radius. It contains grid data and certain aeronautical information such as location of air fields, radio navigation aids, and air spaces. Operationally, it is integrated with ground based radar equipment used for spotting and tracking aircraft and for ground control approach operations. Because it makes possible the rapid determination of aircraft position, it can be used to vector aircraft along scramble, interception, and recovery tracks, to assist air traffic in circumnavigating thunderstorms, to vector aircraft in emergencies, and reorient lost aircraft.

Another development has to do with jet streams. Even though the shortest distance between two points on the earth's surface is along a great circle course, this is not always the fastest route. In recent years considerable attention has been given to the pressure pattern flight technique which is designed to make maximum use of the most favorable winds and air currents. Knowledge of the relationship of wind velocities and air currents, to high and low pressure areas, makes it possible to determine through meteorologic forecasts where the optimum flight path is at any altitude. Great savings in fuel and flying time can be accomplished by knowing the optimum route. Plans are being made to show these jet streams on charts.

One of the greatest scientific achievements of World War II was the development of radar. This product of electronics plays a big part in modern aviation. It is being used increasingly in air navigation and in the new weapons systems. Radar makes it possible to identify certain objects or features on the ground from any flying altitude in darkness or in bad weather. In order to make charts useful in radar navigation (or radar bombing), a technique has been developed which shows a series of simulated radar returns, images of ground objects that are radar identifiable appear on the chart in the same manner and with the same intensity that the images appear on a radar scope. A successful technique has also been developed for compiling a reasonably accurate chart almost entirely from photographs taken of

a radar scope while in operation at a high altitude; the only other source material being a few horizontal control stations to orient the compilation in its current geodetic position.

ACIC also has an important role in the guided missile program. Every long range guidance system will require some type of acutely accurate graphic material, geodetic information, or isogonic data. Both ground detail and geodetic position must be rigidly accurate in graphic presentation. For the first time in history geographic coordinates of points on one continent must be on the same reference datum as points on other continents. Values of magnetic variation have to be more accurately expressed. Gravity anoemalies have to be taken into account. These problems challenge the best ACIC geodesists, surveyors, and cartographers.

Many problems are created by the restricted space in jet aircraft cockpits. Several solutions are under investigation. One involved the use of a projector which projects an image of a chart on a small screen. The chart image moves in synchronization with the speed of the aircraft. This image could thus be compared with a picture of the ground on a radar scope. Other studies are being made to overcome the obstacle of small cockpits: one of them permits the pilot to easily read any portion of several charts simply by turning a knob on a holder fastened to his knee.

Although the description of ACIC products were, of necessity, very brief and only a fraction of the publications were even mentioned, background has been provided for a sufficient familiarization so that a description of the operations involved in producing them will be more meaningful.

Production operations at ACIC progress through four major phases:

(1) Collection and evaluation of various source materials for use in production.
(2) Base compilation.
(3) Final drafting.
(4) Reproduction.

Rarely is construction of a new chart started from "scratch". As in most other fields of science, a start is made with whatever information is on hand. Then, through exhaustive research, additional information is collected. And then, if necessary, action is taken to obtain, by some means such as surveying or exploration, the missing information needed to satisfy the requirements of newchart production or existing chart revision. Ever since man began to draw charts on the shores of the Mediterranean, this process has been going on. The process has been stepped up, though, in recent years, because of the increasingly rigid cartographic requirements of the atomic age. Now it is necessary to dig deeper and to go farther to get the new and more accurate information necessary to improve charts which were considered top quality a year or so ago.

For each assignment, whether for a new chart or for a revision, an organized search is made to collect all materials, such as maps, geodetic control data, intelligence data, and aerial photography that could conceivably be of value in the compilation. All material is evaluated and source material is selected. Compilation instructions are prepared in detail and specify just how each item of source material should be used in the compilation process; how reliable each item is. One source map may be considered the most reliable for geographic position, another best for contours and ground elevations, while a third might be best for character of ground detail. The

compilation instructions also specify the treatment to be given the geodetic control data and aerial photography that is available.

Programs are planned for the acquisition of new aerial photography and geodetic control data as far in advance as possible. Usually these two items are available because they are indispensable source material for the production of an atomic age chart.

About five hundred ACIC employees are engaged in this important first phase of chart production. When each of their assignments is completed, all the instructions and source materials are forwarded to the compilers.

Frequently an assignment consists only of cartographic revision of an existing chart. Additions are made from information found on a new map, a survey, or another new map of a larger scale. Sometimes corrections must be made on natural and cultural ground features shown on the existing chart. A few roads and streams may be added. The alignment and character of some of the roads and streams may be changed. Frequently new towns or villages are added as well as bridges, dams, and large industrial buildings. It is often necessary to add place or feature names and some of the names on the existing chart changed. Marginal data is brought up to date. These additions and corrections are usually made to the compilation bases which were used in producing previous editions of the same chart. After corrections are made to the base the drafting of new color separation plates is accomplished.

Often the assignment consists of an original compilation of a new chart or a more detailed and thorough revision of an old chart, thus bringing into play a greater number of cartographic procedures. It may be necessary to establish a new base or to adjust some of the detail on the old base as a result of the acquisition of new geodetic control data. Sometimes it is feasible to add or change detail by visual reference to aerial photographs or by transferring detail from photographs to the compilation base. When it can be done a new base is prepared by compositing several small strips cut from reduced copies of existing charts or maps onto a base on which only the latitude and longitude lines appear. Any, or all, of several methods may be employed to complete the base.

While a certain amount of this type of cartographic compilation will always be necessary, ACIC is gradually employing photogrammetric processes.

One of these processes is called tri-metrogon. It gets its name from the installation of three cameras, with metrogon lenses of 6 inch focal length, placed in an airplane in such a way that a vertical photograph and a left and right oblique photograph are exposed simultaneously so as to provide continuous photographic coverage of the earth's surface, from horizon to horizon in a direction perpendicular to the line of flight. It was especially designed for and is well suited to much of the charting performed by the Air Force.

The packaged research material is received along with aerial photography. The photographs are indexed and a working plan of compilation is drawn up. Then begins that long journey through the various procedures of photogrammetry by which survey data and map details are produced in a few days. Barely a generation ago it would have taken months or years of field work to do the same thing.

The principal point of each photograph is accurately marked; these points are then transferred to adjacent overlapping photographs in the line of flight. Azimuth lines, back and forward, are drawn from the principal point of each photograph just as a transit traverse is run in the field.

Sharp images are selected and identified for use as radial control points. These images are transferred to adjacent oblique or vertical photographs. These are the points for which accurate geographic positions are established by means of radial triangulation at a later stage of the compilation. Points of known geographic position are marked. (Fig. 1)

The individual photographs are then subjected to a complete mathematical analysis to determine their geometric relationship to other photographs in the strip and to the flight line itself. The result is a set of values for photographic tilt, skew, swing and other orientation factors.

Templets are then prepared from a vertical photograph and its two companion obliques. This is done by means of the rectoblique plotter, which makes it possible to draw lines on the templet representing the planimetric position of imaginary lines on the ground, extending from the photo-plumb point to each of the control points previously selected on the photographs. (Fig. 2)

Photo interpreters carefully study them together with all available intelligence and map information; they delineate the ground features which should appear on the finished chart.

While this is going on, the large scale manuscript base is getting under way. Large sheets of plastic material are fastened together; a suitable projection is plotted on the base; the accurate positions of geodetic control stations are plotted.

Metal templates, consisting of thin metal strips with slots in them, are fastened at one end to a hollow post representing the plumb point are constructed from paper templets. These metal templates are then assembled on the plastic base by beginning at a known control station and laying each successive templet down so that the azimuth lines coincide and the metal strip

Fig. 1. The control selector, like a bio-chemist, examines each aerial photograph. She searches for ground control points appearing in the pictures. These locations, which she marks, link the many ground features in the photograph to a definite geographic point.

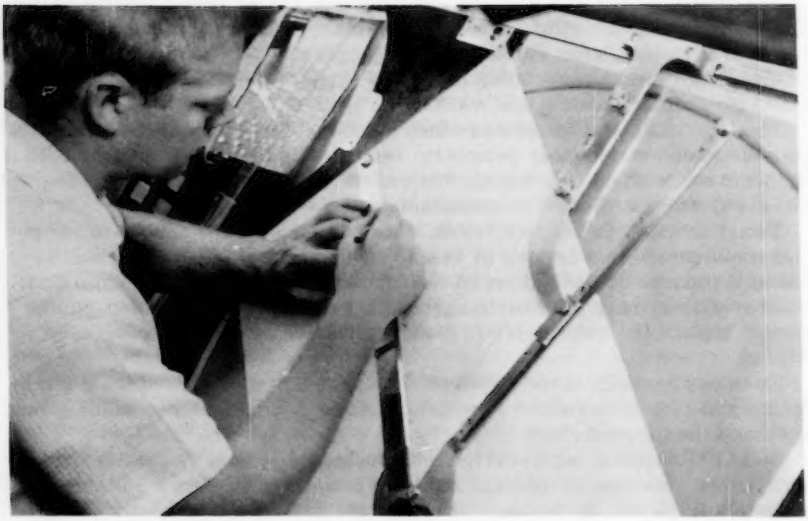

Fig. 2. Using a radial line plotter an aerial photograph is transformed into a paper templet or paper die. Through the imaginary plumb point directly under the camera aircraft, rays are penciled outward to the previously marked geographic control points.

radiating toward each single control point intersect properly. Studs are placed in the slots to allow each templet to assume its proper position in relationship to the other templets. (Fig. 3) When all of the templets are thus assembled and oriented to the known geographic control stations, the process of radial triangulation is complete. All control points, as well as, plumb points are marked and the templet net is disassembled. The photogrammetric base now contains thousands of points representing ground photo images each of which has been located accurately in relationship to all other points and to the lines of latitude and longitude.

The base is then cut in strips and placed in a sketchmaster, where, through a series of mirrors, the image of the photographs appears as though it were projected in a horizontal plane on the base. The ground features which have been delineated on the photograph are then traced on the base. (Fig. 4) The base is edited and inked, then photographically reduced to the scale of the finished chart. At this point, ground elevation and contour lines are compiled and plotted on the reduced base.

This is done with a photoalidade, an instrument which measures the horizontal and vertical angles to a large number of selected points in an area covered by an oblique photograph. (Fig. 5) These horizontal and vertical angles are the same as they would be if they were measured with a surveyor's transit, set up at a point in space where the photograph was taken. The measured angles, together with known values, such as flight altitude, elevations of a minimum number of points in the area, and distances obtained from the photogrammetric base, makes it possible to compute ground elevations of all the selected points.

Fig. 3. A huge, metal spider web grows as metal templets are built on top of paper templets. When complete, pins are driven through the maze of intersecting arms and legs, transferring the geographic control points in the metal templets onto the plastic base of the oversized future chart.

After an area such as this is covered with numerous spot elevations, a careful stereoscopic study is made and the contour lines drawn in their proper location.

The manuscript base is then subjected to a thorough edit, the detail classified for proper symbolization, and the names of the various features are selected. Photogrammetric compilation is complete and the base is ready to enter the engraving phase.

The process just described is used only when trimetrogon photography is the primary source material. There are a number of other photogrammetric processes, depending upon the available source material and the scale and intended use of the finished product. For instance, in making a large scale chart requiring extreme accuracy in all or a portion of it, high precision stereophotogrammetric instruments, such as the stereoplanigraph are employed. (Fig. 6)

Some types of charts require the use of other stereoplotters like the Mahan or the Kelsh Plotter. (Fig. 7)

Much of the ACIC effort goes into the production of aerial photograph mosaics. This process usually involves the preparation of a controlled photogrammetric base over which photographs covering the area are assembled and fastened down. Before this composite is made, all the photographs must be ratioed and reproduced photographically at the base scale. This is done by a process of photo-rectification, which eliminates scale differences due to tilt. Other complex adjustments have to be made for relief displacements.

The final stages of editing and drafting are performed by cartographic specialists. Separation drawings are prepared from all edited base compilations for color reproduction. Instead of drafting in the usual sense, black

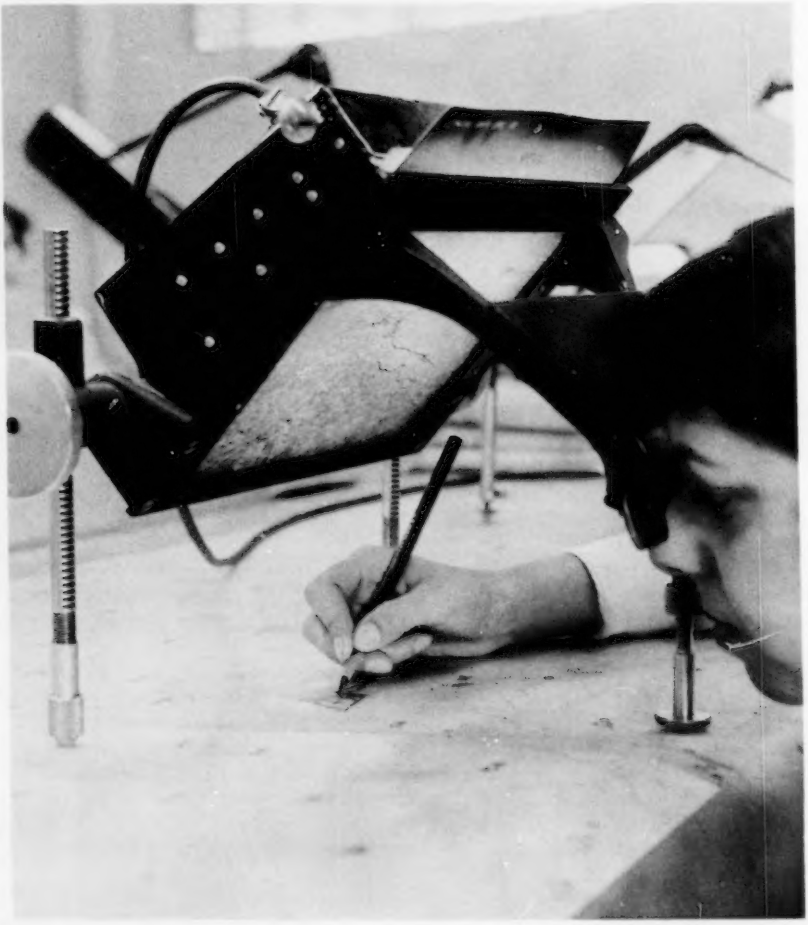

Fig. 4. Getting the information out of a photograph and onto an aeronautical chart is done with a sketchmaster. Its three legs are adjustable to simulate the actual altitude of the camera aircraft. It also duplicates the camera aircraft's tilt position at the instant the aerial picture was taken. Now, all of the guide posts previously set down by others guide the hand as ground details are transferred from the aerial photograph to the controlled chart base.

Fig. 5. Squinting at aerial photographs through a photo alidade, and going through the surveyor's usual mathematical gymnastics, thousands of square miles per hour are surveyed—from an armchair.

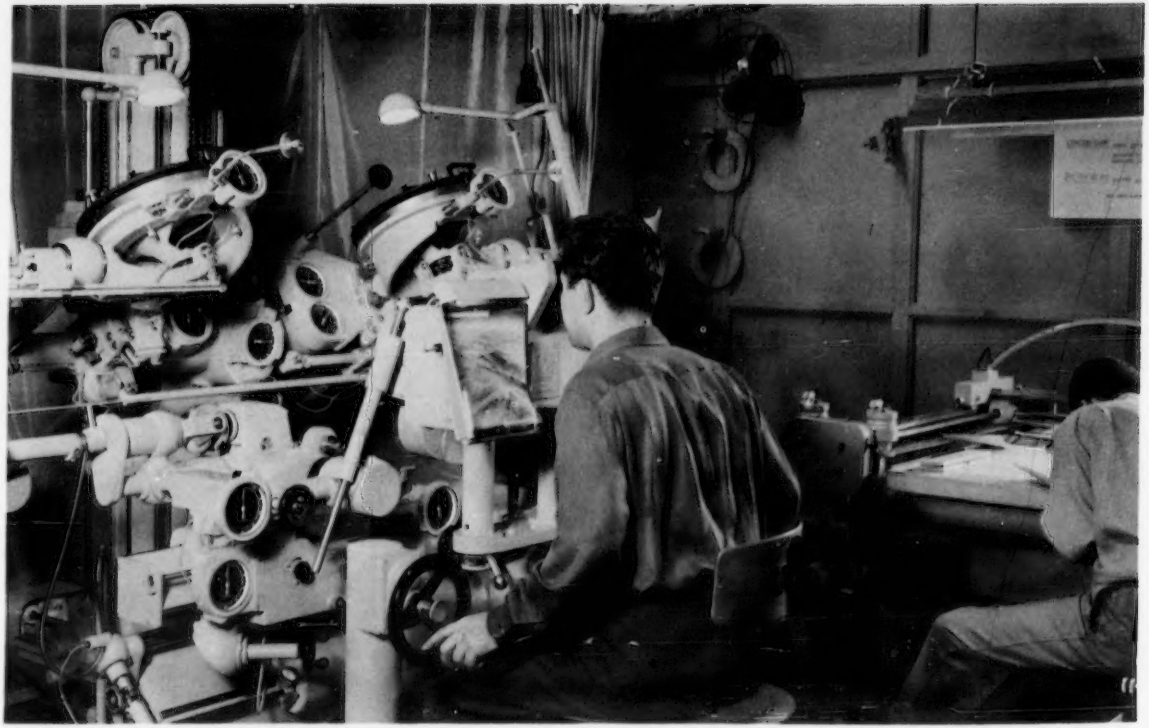

Fig. 6. The Stereoplanograph is used to add 3-D to charts. The operator guides a floating dot, which he sees in the viewer, over the various elevations on an aerial photograph. A planographic stylus traces these contours on a base map.

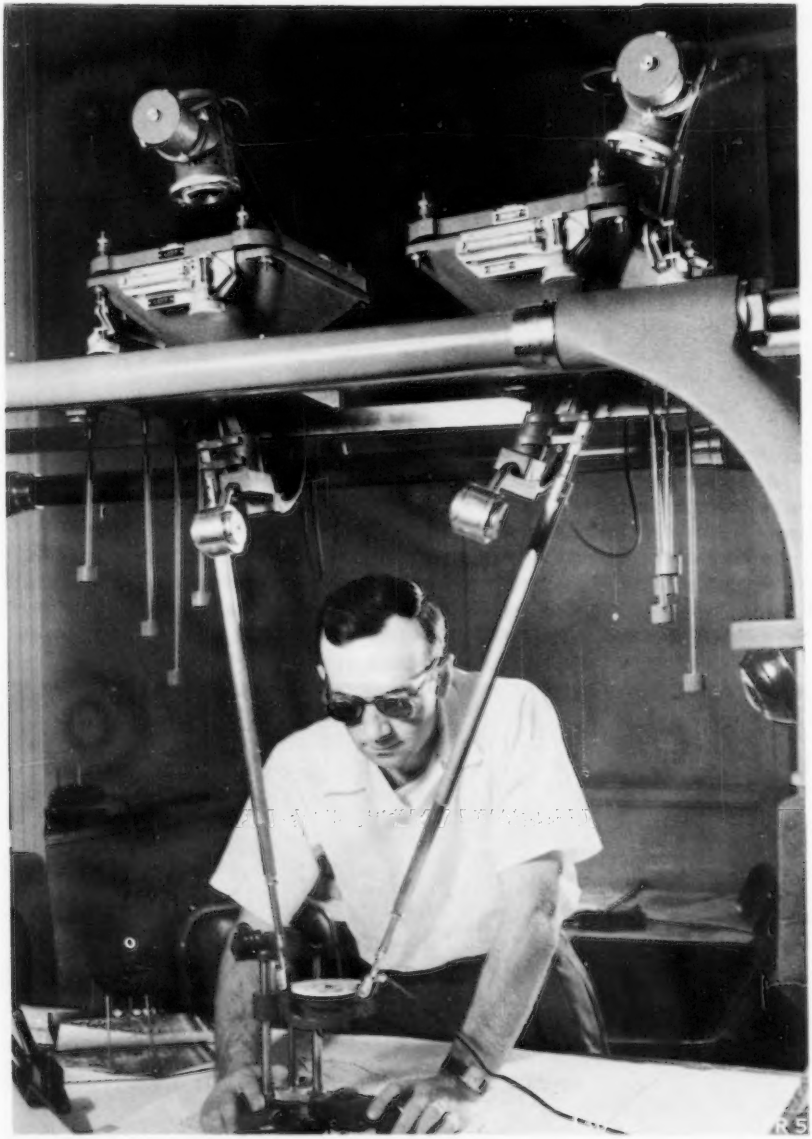

Fig. 7. The pilot of a stereo plotter—goggles and all—carefully watches his altimeter, that records the varying elevations of the land over which he passes. The line of his flight is being transferred to the chart base beneath.

ink on white paper; for about the past five years, ACIC etches-in the chart detail on vinyl plastic coated with a semi transparent resin material. The base chart is placed on a light table, the coated vinyl plastic over the base chart, then with a scribing tool all the lines that are to be printed in a certain color are traced in the resin. (Fig. 8) This is continued until a separate negative tracing is made of every color required to complete the chart. Using this process has resulted in higher quality drafting; it has eliminated several compilation and reproduction steps; thus, substantially reduced the number of manhours required by the old process.

Many aeronautical charts are overprinted with certain aeronautical information which is relatively stable in nature, such as electronic aids to navigation. The ACIC Aeronautical Information Division maintains up-to-date evaluated files of all types of airfields, radio facilities, magnetic information, and the like, to serve as source material for the preparation of the aeronautical overprint.

All finished drawings are forwarded to the Printing Division where, by photo-mechanical methods, photographic negatives are prepared and used to make lithographic plates, one for each of the basic colors which will appear on the chart. Charts are printed in from one to ten colors in quantities as great as 75,000 for a single chart. (Fig. 9)

After the charts are printed, they are folded, packaged, and distributed by bulk shipment to the ACIC overseas offices or by individual shipment to users within the United States.

In view of the increasing and changing cartographic requirements of the Air Force, ACIC places great emphasis on producing charts as economically and efficiently as possible. Efforts along this line have resulted in the development of a number of new procedures and techniques.

Fig. 8. Color separation negatives are made by tracing everything of one color into a resin coated plastic with a stylus.

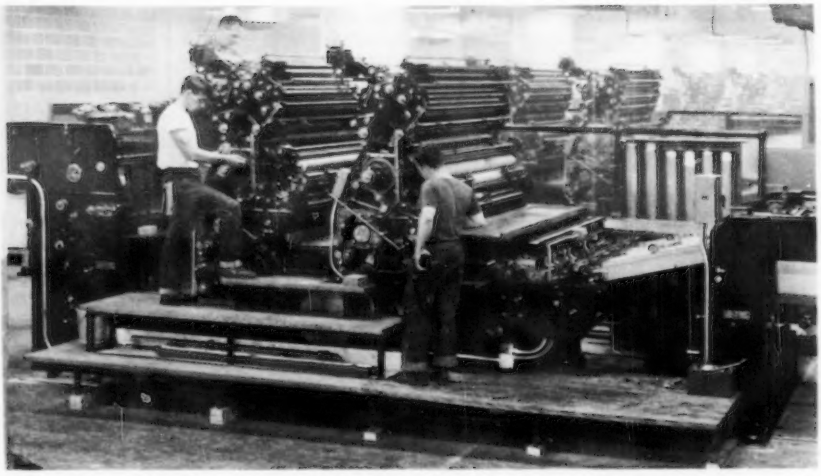

Fig. 9. In the press room of the Reproduction Division, a battery of lithographic presses print charts by the thousands, hour after hour, two shifts a day.

One of these is an improvement in the vignette process. For a long time chart making applied a vignette treatment to charts by producing a band of tint shades ranging from solid on one side of the band, graduating to paper white on the opposite side. It was done by many hours of tedious, hand shading. ACIC's new technique uses a photo-mechanical process. Vignette tones around or within a given outline, such as the shoreline of a body of water, involves the reduction of an open window negative, detailed opaquing, and making a composite sandwich exposure. With the aid of shading screens, utilizing the theory of light dispersion the graduating tint from light to dark is achieved.

Another: since the advent of color lithography, preparation of color separation drawings consumed a great deal of draftsman-artist time. A new technique developed by ACIC utilizes a contour line image to delineate the individual tint areas and eliminates the difficulty of precise inking along the gradient tint areas. Reproduction negatives of the contour lined drawings are exposed on pre-coated lacquer stripping film in the preparation of gradient tint "open window" negatives. A solvent etch is used to clear the desired contour lines and the remaining opaque coating between lines is then stripped off by hand. This new technique reduces the art room time for preparing gradient tint negatives to approximately 25% of the time required by conventional methods.

Another new development grew out of a requirement to show contours at intervals of 100 feet on 1:25,000 scale photograph mosaics. This always presented a problem because the contour lines would not show in the dark areas of the mosaic if printed in black; conversely they would not show in the light areas if printed in white. This was overcome by developing a photo-mechanical technique for compositing contact and projected copy by means of an auxiliary transparent camera back. This arrangement is designed with double vacuum channels and an ability to rotate so that multiple compositing

of both projected and contacted materials can be accomplished with precise registration. Thus contour lines are printed which stand out on any part of a mosaic.

In the development, described previously, of making color separation drawings by engraving chart or map detail with a specific tool on plastic materials or coated plastics, it was still necessary to prepare a film positive from the etched plastic sheet. To eliminate this step, ACIC developed a "Quick Etch" process. A specially prepared dye solution is applied to the engraved coated plastic sheet. It etches and dyes the lines made in the resin coating. A few minutes after the solution is applied, the sheet can be washed and the resin coating scraped off. This leaves a transparent positive that can be used for color separation purposes.

Also in connection with this negative scribing process a dye treatment was developed which renders the resin coated plastic almost completely opaque for reproduction purposes. Considerable touch-up work is eliminated by this method.

For many years cartographers have used a method of pictorial representation such as "shaded relief" to give a three-dimensional effect to their charts. This was done by various techniques involving the use of pencil, crayon, or air brush. These drawings, however, usually produced the desired effect only when viewed from one direction. In order to improve the "shaded relief" technique, ACIC constantly conducts detailed studies of shading and reproduction to achieve a more useful portrayal. Some success has been achieved in combining the pictorial representation with the gradient color tint feature of the chart.

ACIC continuously strives to improve cartographic procedures and techniques in an attempt to keep pace with the rapidly changing world.

The importance of scientific research and development cannot be emphasized enough. The survival of our nation depends upon the progress made in these fields. If the United States is ever called upon to match a potential enemy nation that exceeds it in quantitive strength its only hope may lie in placing proper emphasis on technological superiority and quality.

Science, engineering, industry, and the military share in the responsibility for maintaining quality air power. Present security results from technological advancements made in the past. Future security will depend to a great degree on what engineers are able to do to stimulate and contribute to the overall scientific effort that is necessary.

Paper 1844 November, 1958 SU 3

Journal of the
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STATE RESPONSIBILITY TOWARDS SURVEYING AND MAPPING

Burton R. Ingalls,[1] J. M. ASCE
(Proc. Paper 1844)

ABSTRACT

The state has a responsibility for an adequate surveying and mapping program. There is a need for a new type of service, a coordination and central information service for the industry and profession of surveying and mapping. A new type of state agency can provide this service.

The State Must Recognize Its Responsibility

Intelligent planning for the exploitation of the state's resources and for adapting the land to more intensive use by an ever-increasing population requires adequate knowledge about the land itself, which in turn rests upon the availability of accurate surveys and maps. If the state has a responsibility for its own economic development and provision for the needs of its population, then it has a responsibility for an adequate surveying and mapping program, whether this be carried out by the state or by other public or private agencies.

There Are Three Needs for a Surveying and Mapping Program

Public Works

The state must recognize that the construction of all public works must be preceded by surveys to gather information about the land and that this information is usually presented in a most compact way upon maps. The efficiency, and especially the speed, of performing these preliminary surveys is a major factor in the final cost of such public works. The efficiency with which such

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1. Engr. in charge of the Washington State Bureau of Surveys and Maps, Olympia, Wash.

preconstruction surveys can be run is very decidedly a function of the availability of accurate preexisting surveys and maps.

Private Development

The state must recognize that private economic and industrial development often rests upon managerial decisions which commit large amounts of capital in a relatively short time. Such private developments are marked by great risk and the great speed with which decisions are made and acted upon. If a state is to experience vigorous industrial development, it must provide accurate knowledge about the land upon which can be based bold and sound managerial decisions. This requires better surveys and maps than we now have.[2]

In the competition among states to attract investment capital, the availability of accurate surveys and maps has a pronounced effect on the investor's confidence and has often been a deciding factor in determining the location of industry.

Certainty of Ownership

The state must recognize that as the population grows[3] and the land becomes more intensively used, there is an increased need for certainty in the ownership of land. Uncertainty in the location of land boundaries eats at the core of business confidence and slows private development.

As the competition for land use grows keener, more and more of the land holder's resources are channeled into defending his ownership rather than developing it. Only a small part of boundary conflicts become disputes because most people want to get along with their neighbors, and the quite considerable number[4] of boundary dispute cases on court dockets represent only those who are able to pay for expensive litigation, which is a small fraction of the total amount of boundary disputes.

The Need for Such a Program Is Becoming More Acute

The state must recognize that the three basic needs outlined here are becoming more critical with the passage of time. Sharper demands for speed and accuracy in surveys and maps are unbalanced by greater difficulty in providing these services at a reasonable cost because of the erosion of marks

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2. Washington State, which is about low-average in adequacy of surveys and maps compared to other states, has 11% of area unmapped by USGS, and 42% of state area is mapped only by 15' or 30' quads 20 years old or older. Leaving out salt water coastal areas and the Columbia and Snake Rivers, also unpopulated areas in Cascades and Olympics, there is about one first or second order control monument and one bench mark for every township in the state.
3. Washington State population increased 37% 1940-50, 8% 1950-55 compared to 14% and 9% for the continental U. S. growth (Bureau of Census).
4. No count has been made in this state of the boundary dispute case load, but "quite considerable number" is paraquoted here from Dr. Earnest H. Campbell, Associate Director, Bureau of Governmental Research and Services of the University of Washington, who has done extensive study of Washington State litigation on the subject.

and records, because of public indifference, and because of the confusion resulting from so many agencies engaged in surveying and mapping.

Loss of Monuments

We do not know the rate of loss of our primary cadastral monuments and records upon which our land ownership is based. Certainly they are not lost by natural causes nearly as rapidly as by man-made causes. Experts foresters[5] state that four-by-four wood post section corners and their bearing trees very often survive 50 to 100 years. It is common to have the scribe face on a bearing tree survive both fire and insects when all the rest of the tree has been eaten away.

On the other hand, bulldozers, logging operations, and vandalism destroy the best placed "permanent" monuments in a very short time. The New Jersey Geodetic Control Survey attempts to visit each of their monuments once every ten years.[6] For our less densely settled areas, twenty years would seem to be appropriate.

Fines and penalties are ineffective in preserving monuments and may even work the opposite. Monuments cleverly (but not accurately,) "replanted" by bulldozer operators seem to be the result of statutory penalties. U. S. Coast and Geodetic Survey monuments are "protected" by a statutory penalty for destruction or defacement of the monument of a maximum of $250[7] and/or imprisonment. It may cost four times this to prosecute an offender and a like amount to replace the monument. As a result, offenders are rarely prosecuted, and we have found no record that such a case has ever been tried in Washington State.

Nor is anyone responsible for maintaining monuments. No federal agency has any obligation to maintain section corners in Washington State or any other state, except on federal lands, and no one is required to maintain or recover any cadastral monument in this state, even if he is responsible for destroying or removing same.

Loss of Records

The recording of surveys and land ownership records has been just as disorganized. The counties cannot be blamed for this as their treatment of records was fixed by statute nearly 100 years ago. Because of the inadequacy of these record systems, to file a deed in the county now is equivalent to losing it as far as an owner 100 years in the future is concerned.

So we have seen the curious situation arise where the actual recording of deeds is done in the county, but the business of organizing these records and searching them is a private business and if one wishes information on land ownership, he goes not to the county but to a title insurance company. Thus where government has failed, private business moves in.[8] Here is one instance, at least of socialistic retrogression!

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5. Paraquoting from Dr. Walter H. Schaeffer, School of Forestry, University of Washington, and A. R. O'Donnell, Asst. Supervisor, Dept. of Natural Resources, State of Washington.
6. (Robert G. Blanchard, former topographic engineer, N. J. Geodetic Control Survey.)
7. A $250 fine is authorized by state statute for each game fish over the legal limit in the possession of an over-zealous angler.
8. For another instance of this, see Note No. 12.

Many states have attempted to correct this situation by the passage of Torrens Acts. (The title insurance companies use the Torrens method of filing to keep their records straight.) These acts were passed in imitation of similar acts in New Zealand, Australia, and Europe—but without much regard to differences in laws, customs, and historical development. Thus the Torrens system in the United States is an utter failure.[9]

But this failure is remediable if we only devote some study to the problem, and it is even possible that a suitably amended Torrens Act would be acceptable to the title insurance companies.

Another loss of records has resulted from the every day use of original documents. Because of a lack of appropriations for making reproduceable copies, the state tidelands and public lands records are used daily in their original form and so also are the Bureau of Land Management section line notes. In 1949, the Washington State Legislature passed an act giving microfilm records the legal status of originals, but the counties have progressed slowly in microfilming their records, and most of the original records still suffer every day use.

Another loss of records results from the fact that out-of-state engineering firms and contractors are not obliged to leave records of their engineering surveys within the state. Deposited in a distant place, they soon become a nuisance and are destroyed. But a worse loss occurs because private surveyors consider their data proprietary, like a treasure map. Some of our most valuable cadastral data, therefore, dies with each private surveyor.

Lack of Interest

Public indifference should probably not be underscored so heavily as the indifference of surveyors and engineers to these problems which have been visible for at least fifty years.

At the beginning of World War II, our instrument development was at least twenty-five years behind that of Europe. While such countries as South Africa, India, New Zealand, and Finland have forged ahead with new techniques, our surveying and mapping techniques have become humdrum, repetitive, and unimaginative. Nor can surveyors call themselves "professional" if they refuse to read the current literature in their art, ignore every innovation and new instrument, and fail to take part in the work of professional organizations.

In the meanwhile, labor unions are moving into the vacuum at the bottom and before long we may find that it is the exclusive prerogative of some particular union to look through a transit or level and some other union to draft a plat. This may or may not be a loss to the profession, but it will force changes in our thinking that measuring angles and distances provide the best training for a young professional engineer.

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9. The State of Massachusetts excepted, of course. The Land Court System and an excellent network of control survey has made Torrens practical for Massachusetts. There may be a few other states having limited success with Torrens. In Washington our most populous county, King County, has what is thought to be the largest Torrens registration in the state: 2500 "live" Torrens title tracts in a total of 400,000 tracts of all types, or less than 1%. There has been not one new Torrens registration in King County for the last 25 years. (Figures from King County auditor's and assessor's offices.)

Lack of Unity

The general confusion which besets the whole field of surveying and mapping is at least partially due to the very large number of organizations engaged in performing surveys and making maps.

In Washington State there are 52 federal and 26 state agencies which produce maps. In addition, there are approximately 80 county agencies, 120 city agencies, 49 power agencies, 32 map companies, 10 oil companies, 20 aerial photographic agencies, and at least 41 miscellaneous private agencies all producing maps of Washington areas. This is a total of 430 agencies and organizations to which should also be added 170 or more small consulting offices of engineers or land surveyors planning and drawing maps of areas in this state.

Each of these agencies keeps files of its own work and also files of data from other agencies. This means that every agency must expend considerable time and effort in acquiring and maintaining the records of other agencies and in addition must supply many other agencies with multiple copies of its own work. This is a prodigious waste of recording, duplicating, and filing effort. To demonstrate its magnitude, it can be shown that if each of the agencies listed here produces one page of data and sends it to each of the others, two tons of paper must be exchanged.

Lack of Cooperation

The inefficiencies of multiple agency recording, filing, and cross communication of data would be welcome if by so doing we could reduce the gross waste of the duplication of effort in surveying and mapping projects. This waste reaches down into the taxpayer's everyday experience and is becoming ever more annoying and less defensible.

Such duplication of effort is caused not only by the failure of an agency to inform itself of what data other agencies may have, but also by the failure of many agencies to supply such data even when it is asked for specifically.

There are organizations in the state government of Washington which do not feel that it is their obligation to provide plans, drawings, surveys, or other data to engineers requesting it even if such plans cover structures that were built some time ago.

The New Service Must Be Provided at the State Level

Federal Information Services

The U. S. Army Map Service has established a remarkable central filing system which utilizes punched cards and electronic scanning and retrieving equipment of high speed and large capacity. This impressive layout is no doubt very useful to the military services and to any organization which wishes information on maps anywhere outside of the United States. The service was not designed, however, for the use of local engineers, and even if much of the data were declassified, it would only occasionally be of use to the public in this state.

The Map Information Office of the Geological Survey also provides a valuable service, but since its information gathering is passive rather than active, the office cannot possibly keep abreast of what is going on in this state. The Map Information Office can collect the 8000 or so published maps of the State of Washington, but it has no means to gather up the ten times larger mass of

unpublished maps, plans, plats, and other diagrams scattered throughout our state; and it is this latter data which is of greater value to engineers, cartographers, planners, realtors, and all those who deal with the land in this state.

Certain agencies such as the U. S. Coast and Geodetic Survey help to unify surveying data by publishing the coordinates and descriptions of the more reliable stations set by other agencies, but the author estimates that the Coast Survey publishes only about 50% of the total first, second, and third order control available in the state.

The U. S. Bureau of Land Management provides a valuable service by making available the notes and descriptions of 220,000 section corners and quarter section corners in the state, but this data is far from being conveniently available, however. It is an expensive and time consuming procedure to obtain these notes for a solid block of four townships, for example, or for a whole county. For such practical demands, the U. S. Bureau of Land Management is unable to provide.

County Information Services

The County Road Engineer's Office in each of the several counties is still the best source of much first-hand information about the ground. The engineer, together with the auditor and the assessor, provides most of the information that can be had about property ownership and cadastral monumentation.

The author estimates that there are over 4,000,000 cadastral monuments in the state.[10] Of these, the author estimates that there are, exclusive of the section and quarter section corners and exclusive of all small lots, 170,000 primary plat monuments in the state.

Most of the data on these monuments is not in the hands of the county engineer but is in the private records of land surveyors. The historical development of the counties in Washington State shows that the counties have never been able to cope with the problem of recording and maintaining cadastral surveys.[11]

Even if the county could cope with the cadastral monumentation problem, it certainly is in no position to cope with the map problem or other needs concerning surveying and mapping. One could hardly expect, for example, to reduce the confusion caused by 430 map making agencies in the state by coordinating these under 39 County Road Engineers.

Private Information Services

Perhaps the most convincing proof that there is a need for a central information and coordinating service is that private enterprise is now offering to fill this vacuum. A well-known, large survey corporation in the East is now offering to "not only find the available aerial photography, geodetic control data, and existing mapping on any engineering project you have in mind, but will make sure it is the most up-to-date available, buy it for you at government prices, and send it to you, billing you later."[12]

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10. There are 1,724,250 taxable parcels in the state as of late 1956. (State Tax Commission)
11. See Report No. 42, "The Evolution of Government Responsibility for Maintenance of Land Survey Monuments", Bureau of Surveys and Maps, May, 1958.
12. The Air Survey Corporation, Arlington, Va.

This service may prove to be helpful in obtaining federal government survey and map data, but the author doubts that a private corporation could do much to coordinate the activities of other agencies or to obtain data from other private concerns. We have a great need in Washington State, for example, for an aerial photo index which includes private as well as federal photography.

State Information Services

By elimination of each of the above, it becomes apparent that only the state government can provide the service of a central information and coordinating agency for surveys and maps. The State of Washington has done so by the creation of the Washington State Bureau of Surveys and Maps. The history of this Bureau, its accomplishments to date, its policies, and its program are outlined in Part II of this paper.

History and Policy of the Bureau of Surveys and Maps

Early Eastern State Bureaus

The idea that the state government should establish a Bureau of Surveys and Maps seems to have originated in depression years on the Atlantic seaboard. Fred C. Morris wrote of this need in 1949,[13] and there were earlier writings by Carroll F. Merriam, Benjamin E. Beavin, Philip Kissam, and S. S. Steinberg in correspondence and unpublished monographs.

During the Great Depression in the thirties, the U. S. Coast and Geodetic Survey was instructed to set up a crash program for establishing supplemental control in the states. This program was intended to utilize large numbers of unemployed engineers under the direction of a state organization created for the purpose and which worked under the general supervision and coordination of the Coast Survey. The program was short lived and the results of it were far from uniform in the various states. Some states were caught at the end of the program with many monuments in the ground but very few surveys run. Other states completed sizable networks of control but suffered them to fall into disrepair in ensuing years.

But three eastern states came out of this period, each with a substantial amount of control and an agency to see that it was maintained. Thus were born the Massachusetts Geodetic Survey, the New Jersey Geodetic Control Survey, and the Maryland Bureau of Control Surveys and Maps. These three agencies have much in common with the Washington Bureau. All four bureaus have advisory, coordinative, and public information functions. However, the Massachusetts and New Jersey bureaus appear to stress actual surveying and map making, while the Maryland and Washington bureaus minimize the making of surveys and maps.

It appears that an act proposed by engineers in New York State in 1944 (which failed to pass) and the Washington enabling act of 1951 were both rather closely patterned after the enabling act of the Maryland Bureau.

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13. Morris, Fred C., "Your Land, Surveys, Maps and Titles", Engineering Experiment Station Bulletin No. 71, Virginia Polytechnic Institute, 1949, $0.75. Includes strong arguments for a state bureau of surveys and maps, a workable amended Torrens title, and universal use of state plane coordinates.

The New Jersey Bureau was placed in the Department of Conservation and Development under Mines and Geology. The Maryland and Massachusetts Bureaus were placed in the Department of Public Works.

The original draft of the Washington act would have placed the Washington Bureau in the Department of Highways, but this was changed at the last minute and it was placed instead in the Department of Public Lands, to which in 1957, the Department of Natural Resources became successor.

History of the Movement in Washington

The first attempt to create a Bureau of Surveys and Maps in Washington State was made by a union. In 1942, the Technical Engineers and Architects Union in Seattle set up a planning committee,[14] which in 1943 and '44, worked up two programs to present to the state legislature—one, a state plane coordinate act and the other, a Bureau of Surveys and Maps act. The Technical Engineers and Architects, with nominal but not strong support from the engineering groups, pressed vigorously for the adoption of the two acts but were successful only in getting the state plane coordinate act passed.

The group was told by a legislative hearing committee and the governor to "study the problem further and submit a report to the next legislature."

So on January 11, 1945, the Washington State Committee on Surveys and Maps was created at a conference called by the State Planning Council. The Planning Council was abolished in the same session of the 1945 legislature, but the committee (which now included many prominent engineers) continued its work voluntarily for two years.

They summarized their work in a report, "Modern Maps for Washington", published in December, 1946, after which the committee disbanded. The 1947 legislature failed to take action a month later. In 1949, the bill hibernated. The Surveying and Mapping Committee of the Seattle Section then undertook an ambitious program of letters sent directly to legislators and to possible supporters of the bill. Title insurance companies, the state grange, and timber companies added their support.

In its fourth presentation to the legislature, the enabling act passed in 1951 by a resounding majority. However, the appropriations bill to go with the act did not get out of committee. The Seattle Section Surveying and Mapping Committee tried again in 1953, but many of the former supporters had lost interest, and the legislature was too preoccupied with other matters to get the bill out of committee. The Surveying and Mapping Committee then renewed a one year program of vigorous letter writing and, assisted by the county engineers and the thirty-two member societies of the Puget Sound Engineering Council as well as former supporters, the group was able to secure passage of the appropriations bill in 1955.

The Bureau commenced operations in March, 1956, when the author was hired to take charge of the work.

Political Support

Eleven years elapsed between the conception and the birth of the Bureau of Surveys and Maps. The engineers who fathered this creation quite characteristically take more interest in the conception of a great idea than in the

14. Mr. Harold J. Oliver, chairman.

tedious process of bringing it to maturity. After all, this is their role in society. They are conceivers rather than builders or operators. Engineers, however, should not be so naive as to suppose that a child of theirs will survive if left unattended in the turbulent and roisterous school of state politics. For every service which the state government maintains for its people there is a persistent and vocal group which supports this service in its position of competition with other services for the state budget. If there is no cry from the hinterland in support of a given program, the program will die.

The legislators and executors of the state's services form their policies on the basis of the volume of support from the hinterlands. If there's no support, they must rightfully conclude that there's no interest in the program and therefore it should give way to some program the people are interested in.

Engineers can only blame themselves if the legislation they desire seems to come so slowly. For the political machine is not operated by formulas or logic but is moved by force alone.

Public Relations

The layman often asks, "Well, if you don't make surveys and don't make maps, what do you do?" The abstract program of the Bureau is not an easy one to describe to the layman, and for that very reason it is necessary to be very alert about public relations. The founders of the Bureau of Surveys and Maps realized that its program would have to be sold to the public and even to engineers.

Accordingly, the Bureau tries not to miss any tricks in public relations. In its first two years of operation, nineteen articles have appeared in magazines, newspapers, radio, and television totalling 273 column inches of coverage. In addition, forty-two reports totalling 350 pages have been written, largely covering the technical findings of the Bureau. Copies are not printed in quantity but prepared as needed.

Recording and Indexing Functions

The Bureau has two broad classes of functions, the first is recording and indexing functions and the second—advisory, coordinative, and educational functions.

The recording and the indexing functions can be split up into the survey library, the map library, and the technical library.

The Survey Library

The first project the Bureau undertook in the summer of 1956 was a joint project with the Washington State Library and the Division of Forestry for the microfilming of the U. S. Bureau of Land Management's section line notes. 225 volumes of these notes were condensed into ninety-six reels of 35 mm microfilm, using film and camera supplied by the Bureau.

Within the next three years, the Bureau hopes to be able to cut, splice, and reassemble this film in such a way that all the section line notes and descriptions for one township can be carried in a film can the size of a small spool of sewing thread. Each can would contain about eight feet of film and would cost about 50¢.

The Bureau now has a complete and up-to-date file of all Coast Survey monuments in Washington, Oregon, and Idaho, and all Geological Survey monuments in Washington. By late this summer this will include all of the Corps of Engineers monuments, most or all of Bonneville Power, and some of the Bureau of Reclamation.

For the most part, it is intended to collect records of monuments rather than of surveys, and the file will include coordinates of position and elevation as well as a verbal or photographic description of the monument. There are formidable difficulties confronting such a proposal, but the author feels that recent advances in recording science will make it possible for the Bureau to begin recording monuments in this system within the next two years.[15] It is quite difficult to form an estimate of how many monuments of various kinds there are in the state. Of those which should be recorded in the Bureau, the author estimates that there are 40,000 survey control monuments of first order, second order, and good third order and 400,000 primary cadastral monuments, which include section corners, quarter corners, and plat corners but not lot corners. This total of nearly half a million monuments will require an exceptionally efficient recording system, and so the Bureau is in no great hurry to record a large number of monuments until this system is designed, tested, and proven.

By utilizing the most modern systems of information recording and retrieval, the Bureau should be able within the next eight years to answer a long distance telephone request for control in any one of the following three ways:

a) Within six minutes of initiating the call, the information will be read back through the telephone, or
b) Within eight minutes of initiating the call, the inquirer will be told that the information simply is not available or does not exist, or
c) The information will be in the outbound mail within four hours.

The Bureau now has a central address file of 2,000 surveyors, mappers, and engineers and other persons concerned with surveying and mapping. From this file, gummed address stickers can be prepared for numerous classification breakdowns and categories at a very nominal cost.

The Map Library

Besides the Survey Library, the Bureau maintains a Map Library. Although the enabling act clearly authorizes the Bureau to sell maps, the present feeling is that the Bureau should not do so, or at least not for the present. This policy arises out of two facts—one, that there are many map stores in the state with which the Bureau does not desire to compete and two, the sale of maps might easily burden the Bureau with so much work that it could do little else, especially as soon as it became generally known that the Bureau had a centralized map sales service. A super map store is a temptation for bureaucratic aggrandizement which in time might easily overshadow and finally completely eliminate the Bureau's other activities. It was the feeling of the Advisory Board for Surveys and Maps that these other activities are more

15. For a preview of how this system might work, see Bureau of Surveys and Maps Report No. 23, "The Extended Use of State Plane Coordinates", 10 pp., 7 diagrams, August, 1957.

uniquely a state government function and will have the more important long-range effect on surveying and mapping.

The Map Library will collect at Olympia certain categories of maps. These are:

a) Index maps showing coverages of various large surveying and mapping agencies, such as the Geological Survey, the Coast Survey, and Corps of Engineers. These index maps are usually keys for finding other maps and surveys.
b) Rare maps in the event they are of current value.
c) Certain obsolete maps. Obsolete maps are worthless for a period of thirty years or so following obsolescence and are thrown away by nearly all agencies. However, after this time they increase in value and usefulness. For the lack of some agency to preserve them, most old maps simply disappear, so that it is very difficult to find maps which trace the historical development of a country.
d) Orphan maps—that is, maps of large scale prepared for special uses which lack any other agency interested in caring for them.
e) Mapping data left in the state by foreign corporations.
f) Specimen maps illustrative of certain qualities or methods of mapping.
g) Standard series of large coverage—common reference series as county map series of the Highway Department, the topo quad series of the U. S. Geological Survey, and other similar, fairly uniform, large coverages.
h) Certain maps used primarily for geographical, sociological, or statistical data presentation which are of demonstrable permanent value in planning and regional development.

A second part of the Map Library will be a catalog of all maps of Washington State or any part of the state. This catalog will include all maps held by the Bureau as well as those not in the Bureau collections. Some thirty-five attributes of the map will be indexed as well as a 35 mm microfilm picture of the map. This picture is not intended to be used as a medium of reproduction for the map but rather only to show the general appearance of the map. Copyrighted maps can be photographed with strike lines across them similar to the way that stamps are pictured in a stamp album.

The catalog will cover the 8,000 known published maps of areas of the state as well as an estimated 70,000 unpublished large-scale engineering maps and drawings. To accomplish this, the catalog will utilize punched paper tape, punched cards, magnetic tape, microfilm, and other advanced methods of information storage and retrieval.

Although much progress has been made in the design of this data recording system, the design is not yet finalized and probably will not be for at least two more years. In the meantime, the Bureau is carrying on a moderate program of map acquisition. The maps are entered into small catalogs which serve as pilot projects for testing components of a larger universal map catalog. The pilot catalogs suffice for immediate cataloging needs while minimizing the investment and labor required to make the changes that experience shows are advisable.

At present the Bureau has all of the maps printed by the Geological Survey and all of the Army Map Service quads and has a good beginning in categories a, f, and g noted above.

The enabling act also authorizes the Bureau to compile and publish maps. Not wishing to bring on itself the ignominy of becoming the 431st map

producing agency in the state, the Bureau will strongly resist the temptation to make maps. The reasons for doing so are in this case even more compelling than those reasons for avoiding the sale of maps (above). But there are certain conditions under which the Bureau might undertake to compile or publish a map. These are:

a) The Bureau might publish maps which are indexes to other maps or surveys.
b) The state has a need for a good aerial photo index superimposed on a large scale base map. The Bureau is probably the only agency which would produce such an index, and it most certainly will. Present plans contemplate a book of 100 sheets of diazo-produced maps of the same scale, size, and coverage as the Geological Survey 30-minute quadrangles.
c) The Bureau is now working on an azimuthal equidistant projection centered on the City of Seattle. Several years ago the University of Washington undertook the calculation of five-degree intersections for such a map utilizing the IBM 604 computer to make the calculations. This work was not finished, and the Bureau has undertaken to complete the calculations. An azimuthal equidistant map centered on Seattle will be of great value to the entire state of Washington and is the sort of map that no other agency would probably undertake to produce. Actually, the Bureau's part in this is only to complete the calculations, not to do the cartographic drafting or reproduction. This work should be complete before the end of 1958.

The Technical Library

The third library which the Bureau maintains is a technical library on surveying, mapping, and the graphic arts. There are many mediocre books and textbooks in the field of surveying. The Bureau is collecting the best and the most recent textbooks and technical data books as well as some of the most useful mathematical tables. The collection has now reached the total of 150 bound volumes, 200 pounds or so of magazines, and 1500 other accessions, all of them fully cataloged.

The 1500 "other" accessions comprise all material which is not strictly bound volumes or periodicals. This material consists of clippings, mimeographed reports, letters, pamphlets, catalogs, tabulations, and many other kinds of miscellaneous bricabrac which comprises the most valuable part of the technical library collection.

There have been so many innovations in the field of graphic arts and reproduction, and the art of surveying and mapping has been expanding so rapidly recently, that much of the most valuable material is not in published form. All of this material is indexed in a new system of cataloging which is cheap, efficient, and seldom fails to bring forth the desired data. This system, called a "multi-aspect" system or "coordinate index", is an adaptation of a system invented about twenty years ago but only recently developed and used.

The Bureau subscribes to forty-five periodicals and journals, of which thirty are foreign. It includes such countries as Uruguay, Germany, Mexico, Australia, England, Sweden, Finland, Switzerland, Canada, Spain, Italy, New Zealand, and Poland. Two Russian magazine subscriptions are "in process".

In the field of surveying and mapping, the Bureau has a larger subscription list than the Library of Congress.[16] It would be a herculean task to translate all of these magazines. The Bureau does not attempt to do so, but the magazines are scanned by Bureau employees and other interested persons who have enough background in surveying and mapping to know what is news. When articles turn up which seem to be of greater than ordinary value, these are cataloged in English, which requires less than five minutes of translation time per article. Average labor time for the complete process of cataloging any article is fifteen minutes.

When certain outstanding articles are discovered, the Bureau personnel make abstracts in English which are then mailed to American surveying and mapping magazines or reported in the Bureau's own bulletin (which see below). The Bureau also makes bibliographies and when requested to do so, does make longer and more detailed abstracts or translations. The policy is to avoid becoming involved in tedious translation. The translation services are intended to go only far enough that the user may know for sure whether he wishes to have a complete translation done. It is then his problem to have it translated.

The preparation of bibliographies includes both domestic and foreign sources and is done principally on request. Recently the Bureau completed "An Annotated Bibliography on the Geodimeter and Tellurometer" for example, which lists fifty-three articles.

The Bureau publishes an irregular bulletin mimeographed on two sides of a single sheet of paper in short telegraphic form and bulk-mailed to 1500 addressees. This bulletin headlines Bureau bibliographic findings and other special local news of particular interest to surveyors and mappers in this state.

All of the services provided by the technical library cost the Bureau an estimated $190.00 a month.[17]

Advisory, Educational, Coordinative Functions of the Bureau

The enabling act created a five-man advisory board to guide Bureau policies. This board is appointed by the Washington State Commissioner of Public Lands and serves at his pleasure without salary. Since 1951, the Board has met six times formally and has communicated many times informally. Many policies have not been settled, and in some of these cases, the author's opinions as expressed here may differ slightly from those of the Board. The opinions of the author and those of the Board will probably change toward unanimity before it is necessary to actually fix some of these policies.

Preservation of Monuments

One of the most vexing problems confronting the profession of surveying and mapping today is that of the loss of monuments. It is clear that this was uppermost in the minds of the authors of the enabling act which established the Bureau of Surveys and Maps. The enabling act does not make it clear

16. Many are irregular or yearly publications. Nearly all are highly specialized, quite "scientific" in style and subject matter.
17. Cost per month: subscriptions, $10; bulletin, $40; cataloging and accessioning, $60; search and processing of information requests, $80.

whether or not the Bureau of Surveys and Maps is to actually perform surveys. A careful reading shows that some surveys must have been contemplated, and the Bureau was definitely authorized to compile and publish maps, but the development of the Bureau's policies since the enabling act was passed in 1951 has steadily turned away from the idea that the Bureau should perform surveys or make maps.

It was very early recognized that the loss of cadastral monumentation was a pressing problem of great importance, so the authors of our enabling act wrote as follows (Section 2): "It is the responsibility of the state to provide a means for the identification and preservation of survey points, for the description of common land boundaries in the interest of the people of the state . . ." and (Section 4): ". . . [The Bureau is] authorized to cooperate and advise with various departments and subdivisions of the state, counties, municipalities, and registered engineers or land surveyors of the state for the following purposes: (1) the recovery of section corners or other land boundary marks, (2) the monumentation of accepted section corners, and other boundary and reference marks."

It can be easily seen that there's nothing here which says that the Bureau has any responsibility to put a party into the field to recover or maintain any monument in the state. "Provide a means" means what it says, but the authors of the enabling act realized that the means are not yet fully understood or developed and the provision thereof is going to take some time.

The author's preliminary estimates give 420,000 monuments as the total number that need to be maintained. If each of these is visited every twenty years and the cost if $50 per monument visited, maintained, or restored, this program would require 1.2 million dollars per year.

The enabling act also requires the Bureau to promote the use of the Washington State Coordinate system and the Coast Survey level net and to set up standards and methods of procedure. The Bureau was further charged with maintaining suitable indexes of surveys to prevent duplication of effort and to cooperate with all agencies of local, state and federal government to this end, to assemble and maintain records of all reliable survey monuments and bench marks within the state, and to cooperate and advise with all agencies for the purposes stated in the act.

Although this enabling act is certainly not a model of statutory clarity, it is presently providing for all our needs. After further experience has been accumulated, it may be possible to write better legislation.

It is the author's opinion that monuments can best be preserved by getting them all onto the state plane coordinate system as rapidly as possible. Since monuments become lost more through man's depredations than through nature's erosion, the highest rate of monument loss always occurs in areas where there is the most developmental activity. But such regions experiencing rapid growth are at the same time subject to many platting surveys, site surveys, and other types of engineering and cadastral surveys. If surveyors can be educated to place all of these surveys on the state plane coordinate system, then it matters not what monuments are bulldozed out or what old landmarks are obliterated. This presupposes, of course, that the older cadastral monuments and landmarks have already been coordinated.

The writer believes that ultimately there will be no necessity to maintain or restore any monument. Once the entire state is on the coordinate system, well-set monuments will last as long as they need to, and their replacement

from nearby coordinated monuments is an easy matter if some state agency has a record of the coordinates of the obliterated monument.

In saying that well-set monuments will last as long as needed, it is contemplated that we will have advanced to the point where the monuments, stakes, and other marks of each surveyor will be identified by a unique state-registered brand or identification tag similar to a system now used in California State. It is assumed further that we will have progressed further with the tracer tagging of monuments so that subterranean placements of monuments may be found by electromagnetic detectors or by atomic radiation detectors.

Already a number of agencies require in their standards for monuments a coil of wire imbedded in the bottom of the monument to facilitate the electromagnetic detection of the stone.

There has been some experimentation with radioactive isotopes planted in monuments and detected with a Geiger counter or scintillometer. So far this has not yet proved quite practical, but it is almost certain that the difficulties will be overcome very soon.

The art of photography was developed well over a hundred years ago and has reached a high state of perfection. The author hopes that surveyors will learn to use this novel tool as an aid to the description of monuments, thereby obviating long paragraphs of text.

New Land Survey Laws

The author believes in the gradual establishment by statute of a higher degree of compulsory recording of surveys than we now have.

Out-of-state corporations should certainly be required to leave some sort of record of their surveys in the state. Most of these surveys are engineering and construction surveys which would ordinarily not be recorded at the county level, because they do not involve property. If coordinated, however, the surveys do add strength to nearby cadastral surveys; and even if they are of no cadastral value whatsoever, these surveys are of value in locating utilities in the event of large grading projects or of disaster.

The author would like to see present statutes extended in scope to place cadastral surveys on a full local improvement district basis. Surveying is just as much a public utility as water supply and has a like effect upon the value of the property.

Most corner and boundary problems which seem to affect only two or three disputants actually affect their neighbors too and their neighbors' neighbors, and far beyond that. Uncertain ownership based on faulty surveys is like an epidemic disease. Many years ago when a neighbor's child came down with cholera or typhoid, people thought that that was only the neighbor's problem. Now we know that such diseases are generated from faulty health conditions which extend through a wide area, and this knowledge has caused us to pass laws which favor promotion of sewer and drainage projects by local improvement district methods.

The parallel with respect to land ownership is perfect. Where there is land boundary and corner trouble, it is usually everybody's problem whether everybody recognizes it or not.

It should be recognized that the survey of the land as executed by local improvement district type of statute only concerns the operation of gathering information about the land. The settlement of disputes and actual adjudication

of boundaries is reserved to the courts which can solve this problem in a suit in equity. Therefore, concurrently with establishing a statute for the placing of surveys on an LID basis, we should also write a statute which will make it possible to sustain such a suit using the survey information collected in the LID. Perhaps some way could be found to equitably distribute the costs of such a suit and apply this cost also to the local improvement district assessment.

Canada already has such a system operating, and there is no reason why we cannot adopt such a system. There will be obstacles, of course, which will arise due to the fact that Canada has another body of supporting law which we do not have and certain principles in law which are different from ours, such as the "best-evidence" rule. But these are surmountable difficulties if we apply an engineering type of imagination and creativity to the problem.

As the state plane coordinate system becomes more universally used, it would be desirable to slowly change our statutes to give greater strength to the use of coordinates in the description of land ownership. Our statutes presently place the state plane coordinates in the position of "last choice" for the description of land.

The author would like to see every title pass through definite requirements for title examination and survey certification before it is accepted for recording. It might be possible for the title companies themselves to perform both of these checks under the supervision of some state agency, possibly a state land court.

With respect to the latter, we have an excellent example in the State of Massachusetts. The Massachusetts Land Court has had a powerful influence on the quality of land surveys in Massachusetts, has greatly strengthened and clarified land boundary descriptions, and should take most of the credit for making land ownership in Massachusetts more certain than it is in any other state in the union.

Higher Standards of Professionalism

As part of its program of coordination and education, the Bureau will work for less duplication in mapping. The same areas are mapped at the same scale again and again, each time in a slightly greater hurry than before. The result is not an improved delineation of the land but rather lower grade mapping done faster.

Improved cartographic instruments and techniques have certainly tended to neutralize this situation and improve the accuracy of the base data, but we only have to look at a German or Swiss topographic map to realize how far we are from obtaining a quality product. This comparison is never made but that someone remarks on the fact that German and Swiss labor is cheaper or that the Germans and Swiss have available certain skills which we do not have. Perhaps so; nonetheless the author feels that if we properly utilized our resources, instruments, and cooperative genius, we could outmap anyone in the world.

Cooperative genius is the key to accomplishing this objective. Instead of making each map for a separate, distinct, and specialized purpose, we should learn to make maps on dimensionally stable materials and prepare them on a series of reproduceable separates similarly to the method now used by the U. S. Geological Survey. If one separate is drafted with the hydrography on it, another has the road bands on it, another the county and state boundaries,

another the section grid, another the coordinate grid, and so forth—then this map becomes a multiple purpose map. By combining several permutations of its separates this map can be made to satisfy hundreds of different mapping needs. When a redraft of a separate is made, all effort and attention can be devoted to making a better and more accurate representation of the earth's surface rather than redrawing lines that have been drawn hundreds of times before. It is so much easier to correct a separate than a single manuscript that there is a higher likelihood that the map publisher will be willing to make such corrections.

Even for small map projects, the preparation of separates can show economies over a single draft. Further, the use of separates allows complete control over the choice of colors used in a map. The advantages of separates are endless.

But a program of drafting by separates requires one more ingredient before the separates can become truly universal and multipurpose, and this is that there should be a standard system of map coverages. The product of scale times map sheet size is coverage. If coverage alone is standardized and scale and sheet size are allowed to range through any system of values at will, it will then be possible to take map sheets from four separate publishers, put them together edge to edge and photographically make a new map from the four sheets.

The problem of devising an appropriate scheme of base map coverage requires, of course, much study; but in preliminary investigations, the author has shown[18] that it is possible to grid the entire state at all coverages from 200 feet to 5 million feet by means of only fourteen standard grids. If all maps made in the state were made to fit in the squares of any one of these fourteen grids, in time the grids would begin to fill up like paint on a fly screen. It can be imagined that these grids are like a stack of fourteen standard soil classification sieves, where the square holes in the sieves represent the coverage of each map.

In the proposed preliminary experimental system, the intersection of the wires in one screen would fall over the center of the hole of the screens above and below it. Since each screen is twice as coarse or fine as its neighbor[19] and nearly all maps can be reduced one-half or expanded by two photographically without much loss, it would then be possible to always construct a map on this standard base map scheme which would center or nearly center the object of maximum interest to the client.[20]

Finally, the Bureau will press for greater freedom of exchange for all surveying and mapping data. If surveying and mapping is to haul itself up by the bootstraps to some level of professionalism, it will be necessary that we exchange data with the same freedom that biologists or chemists do.

If every chemist wrote in a different chemical shorthand, there would be no point in chemists exchanging information. If every mathematician wrote his formulae with completely different symbols than had ever been used

18. Ingalls, B. R., "Extended Use of State Plane Coordinates", Report No. 23, Bureau of Surveys and Maps, August, 1957.
19. Every third screen is 2.5 times as coarse as the one below it, all others 2.0 times as coarse as the ones below.
20. The noted Pacific Northwest columnist and author, Byron Fish, has remarked that he lives right on the edge of all available maps.

before, there would be little point in accumulating libraries of mathematical works. Yet every survey and every map which is based on an assumed origin and an assumed azimuth of coordinates is recorded in a different language from surveys using other systems.

It is written that the Tower of Babel was destroyed for the iniquities of men.

Paper 1845 November, 1958 SU 3

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THE ILLINOIS AND MICHIGAN CANAL STATE PROPERTY SURVEY[a]

Charles D. Mitchell[1]
(Proc. Paper 1845)

ABSTRACT

This paper dwells briefly on the history of the Illinois and Michigan Canal and the present day land survey to re-establish the boundary lines of the canal right-of-way in accordance with the original property survey made upon the completion of the Canal in 1847-1848.

The Division of Waterways of the Department of Public Works and Buildings has recently completed the resurvey of the Illinois and Michigan Canal and its Reserves.

The Illinois and Michigan Canal extends from the South Branch of the Chicago River at Ashland Avenue in Chicago, southwesterly to the east side of the Des Plaines River and thence generally parallel and adjacent to that river to Joliet; it crosses the Des Plaines River and then follows generally parallel and adjacent to the north bank of the Des Plaines and Illinois Rivers to its terminus in the Illinois River at LaSalle-Peru. In general, as constructed, the canal was sixty feet wide at the top water line, thirty-six feet wide at the bottom, and six feet deep. Above the top water line the embankments were given a freeboard height of three feet, which, at the slope angle of two to one, made the width of the canal between the top angles of the towpath and berm bank a total of seventy-two feet, and, with the ninety-foot reserve strip on each side, the canal property is normally two hundred and fifty-two feet wide. In the course of its 96 mile length, the canal lies in Cook, DuPage, Will, Grundy, and LaSalle Counties and passes through or touches upon 126 land sections. The Division has now made a survey of each of these sections and re-established by the resurvey, the boundary lines of canal property in accordance with the original survey made in 1848.

Note: Discussion open until April 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1845 is part of the copyrighted Journal of the Surveying and Mapping Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. SU 3, November, 1958.

a. Presented at the ASCE Convention in Chicago, Ill., February, 1958.

1. Civ. Engr., Bureau of General Eng. Div. of Waterways, State of Illinois.

Before telling about this recent survey, it might be well to touch briefly on some of the history of this canal, constructed by the State of Illinois during the years 1836-1848, which played such an important part in the development of this nation, and of the State, whose northern boundary was changed because of it, and in the growth and development of this great City of Chicago.

The first germ of the idea of connecting the waters of the Illinois River with those of Lake Michigan is credited to Joliet and Marquette, when in 1673, after their famed journey to and down the Mississippi from which they returned by way of the Illinois and crossed the portage between the Des Plaines and Chicago Rivers to re-enter Lake Michigan, they reported on this portage as follows: "It would only be necessary to make a canal by cutting through but half a league of prairie to pass from the foot of the lake of the Illini to the River St. Louis, which falls into the Mississippi". The Lake of the Illini is our Lake Michigan; the River St. Louis is our Illinois River. A similar report on the portage between these waters was made by Victor Collot, French Military Engineer, as a result of his explorations made in 1790.

In the early 1800's, the idea of the canal was given frequent consideration and study as an important part of the needed improvements for the development of the rapidly expanding United States. And in 1816, when Illinois was still a Territory, the canal was under consideration in formulating the treaty the United States signed with the Indians. For it was in this treaty that the Indian tribes relinquished all title to a strip of land twenty miles in width, extending southwesterly from Lake Michigan along the line of the Chicago River, the Chicago Portage, the Des Plaines River, and the Illinois River to the mouth of the Fox River. This strip of land measured ten miles on either side of the navigable route across the Chicago Portage. The boundary lines of this strip became known as our two Indian Boundary Lines, part of which lines are still very much in evidence even today. And in 1818, when the Illinois Enabling Bill was brought up in Congress, an amendment was proposed and agreed upon to set the northern boundary of Illinois some 50 miles north of the latitude of the southern extremity of the lake, where it was originally proposed, setting it at forty-two degrees and thirty minutes north latitude. The purpose of the amendment was to give Illinois a coast on Lake Michigan and to insure that Chicago, the point at which the proposed canal had always been planned to connect with the lake, would be within the limits of Illinois, and the entire canal would be under one governing unit.

The first survey of a route for the whole of the Illinois and Michigan Canal was made in 1824 by Justus Post and Rene Paul. On March 30, 1822 the Congress of the United States passed the Federal Act authorizing the State of Illinois to open a canal through the then public lands to connect the Illinois River with Lake Michigan. This act also provided that the State of Illinois be authorized to survey and mark the route of this canal and further provided that ninety feet of land on each side of the said canal shall be reserved for the canal. In 1823 the State Legislature appointed a Board of Commissioners for the Canal and this Board then engaged Justus Post as engineer to survey and locate the most desirable route. To expedite the work, which was done in 1824, the Commissioners employed the second engineer, Rene Paul, and divided the survey group into two parties. One party started at Lake Michigan and worked south and west. The second party started at the Illinois Rapids and worked north and east until the two met. As a part of their report, engineers Post and Paul prepared two maps of the canal survey. These maps are entitled "Map of that part of the State of

Illinois through which it is contemplated to construct a Canal," by J. Post and R. Paul, 1824. One of these maps was preserved by the State as a part of the canal records and is now in the State Archives. The second map was transmitted to President Monroe. Neither the engineers, the Canal Commissioners, nor the General Assembly appear to have recommended or adopted the route shown on this map as the definite location. Though the State had the authority, they were still without funds to build the canal. They petitioned Congress for a grant of land or lands through the sale of which the State could raise the money to finance the cost of construction. The Federal Act of March 2, 1827 granted the lands to the State for this purpose, describing the quantity of land as "a quantity of land equal to one-half of five sections in width, on each side of said canal, and reserving each alternate section to the United States. It also provided that the land grant would be adjusted as soon as the route was located and agreed on by the State. The State Act of January 22, 1829 made it the duty of the Canal Commissioners to select the route. A new survey for the route was made by James Thompson in 1829 and the map prepared by him, indicating the route he had selected, was adopted by the Canal Commissioners. And in December of 1829 they selected the odd numbered alternate sections for the State and these were granted in fee simple. The United States retained the alternate even numbered sections. The Thompson map was transmitted to the General Land Office and has always been considered by that office as the map of definite location of the canal. Other surveys for a route were made by the War Department during the years 1829, 1830, and 1831. And between 1830 and 1833 James Bucklin surveyed routes for both a canal and a railroad when there arose the question about which should be built through this territory. But these surveys appear to have little or no effect on the final location for the canal whose route was changed again by the time of the actual construction which didn't get under way until 1836. Then with the authority to start construction, the Board of Canal Commissioners employed William Gooding as Chief Engineer and under his direction a new survey was made to definitely locate the canal for the construction operations. And even this route was modified as the actual work on the canal progressed.

The surveys so far mentioned in connection with the canal all had only to do with the route it was to take. The project of surveying and marking property boundary lines was to come much later. Construction on the canal was begun officially with ground-breaking ceremonies on July 4, 1836. Less than a year later came the Panic of 1837 which ushered in years of business depression. Work on the canal was interrupted for lack of funds. Revisions were made in the original plans to cut the costs of construction. In 1843 the Office of the Commissioners was abolished. A Trusteeship was created in 1845 as part of the plan to finance the completion of the work. By the Act of January 6, 1836, the General Assembly had reserved the 90 feet on each side for possible future enlargement of the canal. On July 12, 1845, the Canal Trustees ordered the Chief Engineer to establish the location of the line of demarcation between the canal lands and the abutting lands held in private ownership, and to prepare permanent records. The order stated: "The Engineer shall cause a plan of the Canal and the lands immediately adjacent thereto to be made upon a scale sufficient size to represent clearly the position of the dividing or boundary line of every individual owner upon the line, and the direction of said boundary line for 20 rods or more, and whenever the feeder lines may be determined upon -- the same shall be done

in reference to them in order that there may be on file at the Canal Office the means of knowing precisely the situation and extent on the line of Canal of all owners of private or individual property as well as of that belonging to the Canal itself." The Chief Engineer assigned the work of establishing the canal boundaries, and the preparation of the record maps and plats, to Artemus J. Mathewson, a surveyor on the engineering staff. Other than the information contained in the order of the Trustees, the canal records, so far as known, do not indicate what instructions Mathewson received as to locating the boundaries. The field work conducted by Mathewson involved taking the canal as he found it constructed upon the ground, establishing the width of canal, and from the canal establishing the boundary, or, as they are generally known, the 90 foot reserve lines. The canal lines and boundary lines were then connected to the lines of the public surveys, the Government Surveys, and the various measurements of courses and distances recorded in field books. From the field notes, Mathewson prepared a series of working drawings covering each section of land through which the canal passes. These drawings are a plotting of the field notes, and show the various lines established, the detailed measurements taken, and other data relative to areas, and so forth. As a final step, a series of record maps or plats were prepared, one plat for each section of land through which the canal passes. These plats were bound in three books which books were evidently intended to be the final or official record of the canal property survey. Mathewson completed his property survey in 1848, the same year the canal was opened to traffic.

The canal was officially opened on April 16, 1848 with boats being started simultaneously from LaSalle and Chicago for their first trip along this 96 mile remarkable waterway. From its very opening the canal was a success; within five years the entire cost of the canal was paid for from the receipts for the sale of canal lands of the 1827 land grant and from earnings of the canal itself. Traffic rose steadily until the middle 1880's but declined after that. The railroads came not long after the canal was opened and the canal lost to this competition.

The canal gradually fell into disuse and obsolenscent as a useful commercial waterway. Studies and infrequent reports were made relative to the problem of future use and disposition of the canal but nothing of a positive nature developed. In 1944 the Division of Waterways issued a report outlining the principal problems relating to the canal and recommended the establishment of a Commission to investigate all problems relating to the canal and to formulate policy relating thereto. Such a Commission was created in 1945 and in 1947 submitted its report to the General Assembly. The Commission concluded that before the State of Illinois could rectify these problems it would be advisable to secure a conveyance in the nature of a quit claim deed from the United States to the right-of-way of the canal. Accordingly, a bill was introduced in the 80th Congress (H. R. 1628) and on July 1, 1947, it was approved as Public Law No. 152, thereby relinquishing to the State of Illinois all such right, title, and interest, if any, of the United States to any part of the land comprising the right-of-way of the Illinois and Michigan Canal.

In the same report in 1947 to the General Assembly, the Commission also recommended that an appropriation be made to the Department of Public Works and Buildings for a full and complete survey of the right-of-way of the Canal. The purpose of this modern-day survey is stated as follows: "to locate and re-establish by field resurvey, the boundary lines of the

right-of-way of the canal and its reserve strips throughout the entire length of the canal in accordance with the property survey made by A. J. Mathewson upon completion of the canal, to locate all encroachments upon canal property, and to determine adjacent land ownerships".

In the execution of this present day project each land section through which the canal passes or touches upon was first resurveyed in the field, along with the location of the canal therein. Next, the survey of the canal and its reserves as made by Mr. Mathewson, using copies of his original field notes and plats, was then fitted by calculation within the completed land section. Following this office adjustment and fitting of these boundary lines by Mathewson to the section survey, these boundary lines were then laid out in the field, their location being marked by some permanent marker, in most cases a standard Division of Waterways tablet set in concrete. The surveys were begun at the eastern terminus of the canal at the South Branch of the Chicago River at Ashland Avenue in Chicago and progressed in a southwesterly direction to its terminus in the Illinois River at LaSalle-Peru. A plat of survey, at the scale of 1 inch equals 200 feet, was prepared for each land section and these are numbered in that order, beginning with Number 1 at the eastern end and continuing through to Number 126 at the western end.

Before the work in any section could begin, however, a considerable amount of time was spent in research and investigation of all available data that would help in the location and establishment of the true section lines and corners. Records in the county offices, of plats and surveys, and of property ownership, were examined; state and county highway engineers and county and private surveyors were contacted for their knowledge of lines and corners; and in the field, the property owners too were contacted for available information. It is doubtful that Mr. Mathewson had any such problem about the location of the section lines and section corners in his day. For his survey followed by less than 30 years, the original government surveys of these lands. With those records in hand, and who knows but perhaps some of his party personnel may have helped on that government survey, he probably had little or no difficulty retracing that survey and locating the original section corners and lines. In fact, in more sections than not, Mathewson's values along the lines are the same as those on the government survey, though occasionally he does show a slight difference in the bearing or some minor difference in the chain length of a line.

In this survey, the lines and corners were accepted where and as they were found already established. Infrequently more than one location or marking of a corner or one which did not fit with accepted lines might be found; in such cases that line or corner (or both) was accepted which was believed the more reliable. In all sections though, this survey included the running of all the section lines, exterior and interior. A traverse line was also run along the canal across each of the sections, which was used not only for the canal studies and other related work, but also for strengthening the section calculations. The distances and the angles shown on the plat are those from this survey, adjusted out for closure for the section and quarter-section.

Next came the fitting of Mathewson's survey of the canal and its reserves to the completed section survey. This would appear to be a simple mechanical process of using his record distances along the section lines from the nearest corner, and his meander of the reserve lines across the section, and making an adjustment or proration of any error for closure. Basically

that was the procedure but it didn't work out quite so simply. In running out the section lines across the canal, Mathewson recorded the distances as he found them, coming first to the reserve line, then to the top angle, (of the berm bank or of the towpath), across the canal, and then to the other reserve line. In this running of the section lines, a careful effort was made to do the same, not to the reserve lines which were no longer marked, but to locate the top angles of the berm bank and the towpath. The new measurements were not always in agreement with Mathewson's distances to these same points. This indicated a possible error in his measurement (which was found in a few isolated cases), but more probably, a different location for the section corner or line by this survey than the one by his survey. In actual practice, the best results were obtained by accepting the location of the canal as it was found, in relation to the section line and corner, — much like Mathewson did when he made his survey back in 1848 — and then accept his distances, along the section line, from the canal line to the reserve lines. The next, and about the most critical part of the procedure, was to determine the angle of the canal at the section line to set up an entrance bearing for Mathewson's courses across the section. Mathewson's bearings were recorded to the nearest five minutes. Using the angle determined by his bearings was therefore not so accurate as desired — and any difference in the alignment of the section line also effected this angle. Again, it was found in practice that the best results were obtained by taking the canal as located. So along with carefully locating the canal at the section line crossing, it was necessary to carefully locate the canal with respect to the traverse base line along the canal across the section. Actually this traverse line was a rerunning of a line which was run in 1936-37 along the full length of the canal. One of the purposes of that survey was also to locate and record the location of the canal at that time. Working with data from that and the present day survey, it was possible to arrive at a true direction of the canal at the section line crossings and thereby arrive at an entrance and closing bearing for the reserve lines. Between these the bearings were then set up for the reserves across the section using the deflection angles determined from Mathewson's bearings of the different courses. Then a trial table was set up and calculated for closure of his reserve line across the section. The resulting error of closure would indicate almost immediately how well the fitting would be. On the whole, Mathewson's survey checked out very well, the error of closure would be small, and the correction amounted to little more than applying a slight chain ratio. In fact in some cases, sometimes more than one trial table was set up, it was found advantageous to apply a chain ratio to Mathewson's courses in setting up the tables. After completing the adjustment for the error of closure new adjusted course lengths and bearings were then calculated. Occasionally, there might be difficulty and this would be evident immediately by the nature of the error of closure. Then the location of the trouble was a matter of patient study and search. Trial tables were always set up for both reserve lines and worked out both so that the closing errors could be compared in case there might be some trouble in one or the other or both. Mathewson's notes were compared with his plats to see if they agreed in bearings and course lengths. In a few instances, it was found he might have errored in recording the direction of a course, as in going around a curve and changing from one quadrant of the compass to another; such as North 89° West instead of South 89° West. In other cases there was an evident error in recording a chain length of a course. Though he

meandered the reserve lines separately and the respective courses were not always parallel or equidistant, they were usually close to that and examination of the notes or plat might lead to locating an error. It was also a help to prepare a new plat of the section with the canal accurately plotted from its location in respect to the traverse line, and on which to plot Mathewson's survey, and see graphically the location of a possible error. After completing the fitting of Mathewson's survey to the section, calculations were made for the intersections of the reserve lines with the interior section lines. And to help and expedite the setting of the reserve line points in the field, calculations were also made for ties between various points of the reserve lines and points along the traverse base line. This helped not only to set the points in the field but also provided checks to be made as the field work progressed across the section. The final calculated values for the reserves were also plotted and this would show how well the lines would fit the canal before sending the work out to the field. The survey party then proceded to set and mark the reserve line points in accordance with the data determined by the calculations. The setting of these points was carefully recorded, its fitting with the canal noted, and the points properly referenced to facilitate future recovery. And when the field work of setting the points was completed, the field book was returned to the office for check and review and the data, reference ties, etc., added to the plat. Later, after all the work had been properly checked and approved, the original tracing for the Plat, and the field book, containing a complete record of the survey, both field and office work, are transmitted to the State Archives building in Springfield for permanent record.

In general, standard survey practices were employed in the execution of this survey. A twenty-second reading transit was used in the field work, with standardized steel tapes, and the usual assortment of survey equipment of a field survey party. The specifications for the chaining required the use of tension handles, taking of all measurements on the horizontal, with the proper corrections applied for temperature. The lineal error permissable could not exceed 1;10,000. The angles were required to be read or repeated six times, with the permissable angular error limited to five seconds per angle. The general practice of entering the field notes in a narrative form was followed, with emphasis on full descriptions and complete sketches along with the notes to provide the utmost clarity and unmistakable record of the exact surveying procedure followed. These notes were recorded in one of the standard topographical field notebooks which are somewhat larger than the standard transit notebooks. This larger size removed any need for the crowding of notes, and it gave ample room for computations to be made by the party chief, and for the office work and computations. For the decision was made, when this project was started, to insure the preservation of a complete record of all notes, computations, and related data, to have one such field notebook for each section surveyed and enter both the field and office work in this one book. This was preferred to having a separate set of papers for the office part of the work which might become lost, separated, or possibly destroyed. So the field notebook used, though somewhat bulky in size and not so convenient for carrying in the field, contains the complete and all important record of every phase of this survey, one for each section, from beginning to end, and numbered in order with the corresponding plat sheet for each section.

This property survey as mentioned earlier, is the resurvey in accordance with the notes and plats of the survey of 1848. There are some who might

question the legality of these boundary lines but that is a legal problem relating to titles which has been most thoroughly investigated by Mr. Walter A. Howe of the Division of Waterways and published by the Division in 1956 under the title "Documentary History of the Illinois and Michigan Canal — Legislation, Litigation, and Titles". It is unfortunate that the property survey made by Mr. Mathewson was never filed for record. In fact for many years the notes and other records were in the personal possession of Mathewson and not retained as official canal records. Fortunately, though his survey was not recorded, his notes, documents, and records of the survey were recovered and returned to the canal offices and later to the State Archives. And the resurvey of those same canal boundary lines, as they should more properly be called, in accordance with those notes and records, is that which has been recently completed and is called the Illinois and Michigan Canal State Property Survey.

Paper 1846 November, 1958 SU 3

Journal of the
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Proceedings of the American Society of Civil Engineers

PHOTOGRAMMETRY AIDS IN PIPELINE LOCATION SURVEYS[a]

Alfred O. Quinn,[1] M.ASCE
(Proc. Paper 1846)

The development of photogrammetric techniques and the increased use of aerial photographs for a wide variety of engineering studies have provided the pipeline location engineer with valuable aids to assist him in determining the most economical route for his pipeline.

The basic requirements for pipeline location surveys have been outlined by Mr. Earl K. Monteith in his paper published in March, 1958, by the Pipeline Division as Paper No. 1574 of the Proceedings of the American Society of Civil Engineers. Mr. Monteith says,

> "A pipeline survey has several purposes which all must be considered in their proper proportions simultaneously as the survey progresses. These purposes are, first, to pick the most economic route possible and mark it so that construction forces can readily find the route; gather all information necessary for preparation of route maps, showing all properties and surveys crossed by the route; and to gather all data which might be useful to design personnel, and all data needed to acquire right of way and permits to construct the line."

The preliminary study of a proposed pipeline route requires a review of any existing topographic maps of the area, and if government aerial photography is available, these photographs should be obtained. Government agencies, such as the Departments of Agriculture, Interior and the Army, have extensive photo coverage of various parts of the country. These photographs are usually at scales of 1:20,000 and smaller, and are too small to be of use for detailed studies or for relatively large-scale topographic mapping. However, the photographs can be exceedingly valuable in an overall review of the area to determine major rivers and streams, lakes and swamps, urban and industrial developments, and when used stereoscopically, general topographic conditions can be studied. When government or other small-scale maps are not available, these maps can be prepared by photogrammetric methods. A large area for initial study can be flown with the actual mapping restricted to

Note: Discussion open until April 1, 1959. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1846 is part of the copyrighted Journal of the Surveying and Mapping Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. SU 3, November, 1958.

a. Presented at the June, 1958 ASCE Convention in Portland, Ore.

1. Chf. Engr., Aero Service Corp., Philadelphia 20, Pa.

the routes of possible interest. Topographic maps at a scale of 1" = 2,000' or smaller, showing 10' or 20' contours, should be available to make the first route studies. In most mapping projects, the aerial photography is a minor item, say 5% to 15% of the total costs. After the aircraft is on station and favorable weather is available, extensive photographic coverage of possible areas of interest can be obtained at a relatively small cost. Full photographic coverage can provide assurance against the possibility of overlooking the most feasible routes.

Before proceeding further with a discussion of the use of the aerial photographs, it might be well to review briefly their inherent qualities. An aerial photograph is not a map. An aerial photograph provides a pictorial representation of the terrain and depicts upon a flat surface all topographic features, whether hills or valleys. Fig. 1 shows the geometric conditions that exist

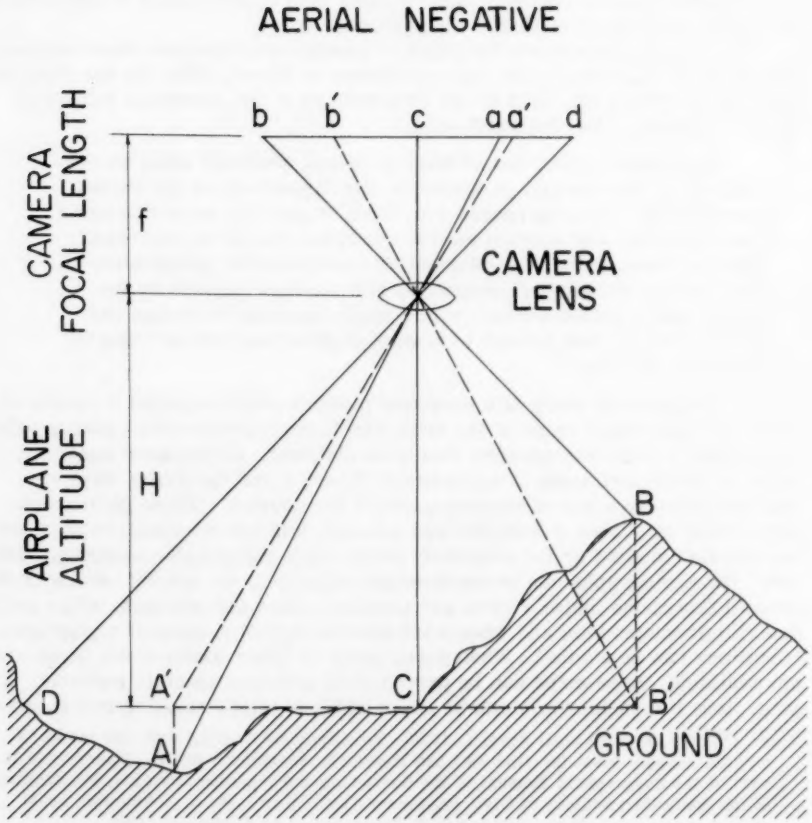

FIGURE 1

on the photograph. The displacement of features, called "topographic relief displacement" by photogrammetrists, provides the fundamental effect required to achieve stereoscopic vision when a pair of overlapping photographs is viewed, but this displacement can be most confusing when single photographs are used. In Fig. 1, A and B are low and high points on the terrain included in the photograph. The true distance between these two points is measured by A' B' — the horizontal projection of each point onto a datum plane. The position of the true location of points A and B are shown on the photograph as a' and b'. The measure of the relief displacement is aa' and bb'.

In pipeline location, the ideal line would be a straight line between two terminal locations. Because of the relief displacement on an aerial photograph, a straight line drawn on the photograph over rolling or rugged terrain may not be a straight line on the ground. Serious property problems have arisen through a failure to recognize this apparent limitation in the use of aerial photographs.

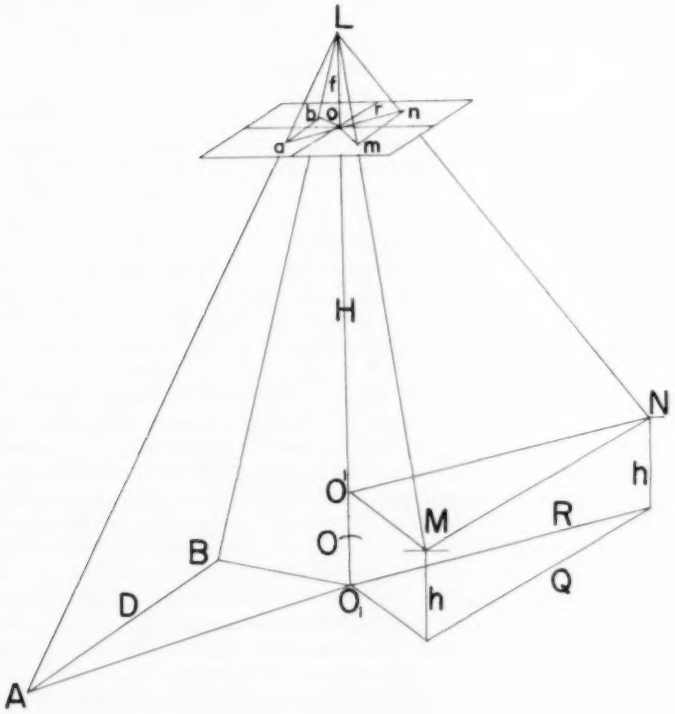

FIGURE 2

GEOMETRY OF AN AERIAL PHOTOGRAPH

A further problem in the use of the photographs themselves is the fact that the original photographs may have been taken at a time when the camera axis was not exactly perpendicular to the ground. This results in producing photographs that are tilted, and these phenomena can further complicate the spatial geometry of the aerial photograph. A tilted photograph contains additional displacements caused by the tilt. See Fig. 3.

The possibility of these two major displacement effects — topographic relief and tilt — occurring on aerial photographs must be recognized in the preliminary planning of a pipeline. In fact, the very reason that relief displacements do occur on the photographs enables us to achieve stereoscopic vision using adjacent overlapping aerial photographs. Fortunately, the effects of relief and tilt can be corrected in modern stereophotogrammetric plotting equipment, and experienced photogrammetrists can produce accurate topographic maps.

Preliminary location can be made using existing topographic maps and/or aerial photographs, but further engineering studies of the proposed route are desirable before finally negotiating property easements or rights-of-way. Low altitude photographs at a scale of 1'' = 1,000' or larger can be secured

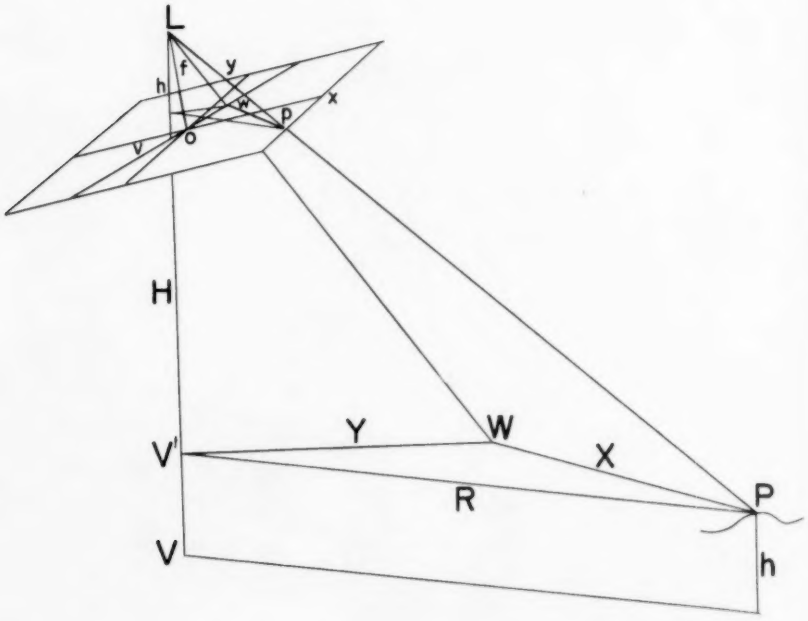

FIGURE 3

GEOMETRY OF A TILTED AERIAL PHOTOGRAPH

at reasonable costs, and a careful study of these pictures by photo interpreters specially skilled in photogeologic studies and soils analysis can provide detailed data as to soil and rock conditions. They can estimate bedrock depth, overburden composition, corrosiveness of soils and the location of granular deposits and other materials. Experienced photo interpreters also can delineate drainage systems, marsh and swampy areas, slide areas, desirable river and stream crossings, land use (including industrial and urban development possibilities), highway and railroad crossings, and provide valuable information concerning property boundaries. These basic route location data can point out the problem areas and materially assist in the selection of the most economical pipeline route. The cost of obtaining this information from the photographs and making spot checks in the field may range between $100.00 and $200.00 per mile, depending upon the location of the job and the nature of the terrain.

In conjunction with the photo interpretation studies, maps showing 5' contours at a scale of 1'' = 200' or smaller can be prepared in areas where the selection of the route will be affected by the topographic conditions.

The design and production of topographic maps by photogrammetric methods require some ground control in order to determine the spatial orientation of the aerial photographs in the stereoplotting instruments. In many cases, it is possible to utilize existing government monuments. When reliable maps are available, coordinates and elevations can be scaled from these maps to provide control data for more detailed topographic maps along the pipeline route. By utilizing "bridging" techniques, the photogrammetrist can extend and establish additional control between areas of existing ground survey points. This method is easily understood. Consider a strip of overlapping aerial photographs between areas containing reliable horizontal and vertical control. Precise stereophotogrammetric mapping instruments, such as the Wild Autograph A-7, are used to orient each photographic pair of pictures and to record accurately the horizontal and vertical coordinates of images located on the photographs that span the area between the existing ground control. The accuracy of the resulting maps cannot be better than the control which is used. For this reason, the accuracies required for the pipeline design should be reviewed, and the methods to be used in producing the maps should be designed to meet the required accuracy.

Whenever it is necessary for the photogrammetric engineer to establish additional horizontal and/or vertical control by ground survey methods in order to meet the accuracy requirements, he can provide monuments which can be used by the surveyors who are charged with the responsibility of staking the final location of the pipeline. The existence of these markers can provide tie points for staking traverse and the location of underground utilities and obstructions. Aero Service has used the Tellurometer, a new electronic distance-measuring instrument, to establish precise distances at a minimum of cost and time required for such surveys. The Tellurometer is not the "cure-all" for every survey problem, but when properly used, the instrument can provide highly reliable distances between line-of-sight points. The instrument does not measure angles. When used for traverse work, a theodolite is used with the Tellurometer.

As stated above, the pipeline location engineer may make use of several route location aids:

1. available maps
2. aerial photos
3. topographic maps from aerial photos
4. ground surveys
5. detailed studies of terrain conditions, including the visual location of property lines from the aerial photos.

In addition, the location engineer may request profiles along one or more possible routes in order to complete his studies. The profiles can be obtained photogrammetrically. The accuracy of the profiles is a function of the height from which the photographs are taken and the acequacy of the ground control information to be used. Careful advance planning for such work enables the photogrammetric engineer to provide reliable profiles along the proposed routes.

After the final location has been made, the route can be drawn on the maps or the aerial photographs and given to the staking party for marking on the ground.

In addition, standard plan and profile sheets can be prepared for the construction parties. Many pipeline companies may find it helpful to have the plan portion of these drawings prepared showing the final route superimposed upon a photographic background. Formerly, this was accomplished by using a photograph enlarged to the proper scale. It is impossible to make accurate measurements on this photographic reproduction. Now, using a new technique, a map called a "Photo Contour Map" can be prepared in which the photographic information is projected onto the map, making corrections for changes in elevation and tilt of the photographs. In this way, the inherent errors of topographic relief and tilt are eliminated, and the final map is a true orthographic projection which will meet the requirements of horizontal and vertical accuracy. There again, the aerial photographs can provide information to assist in the acquisition of rights-of-way and to determine access routes into the pipeline location.

Unquestionably, the wealth of data which can be obtained economically and reliably through the use of a planned and carefully integrated photogrammetric program will make it possible for pipeline engineers to make better decisions in less time for the location of pipeline routes. Consultation with reliable photogrammetric engineering concerns will provide the basic surveying and mapping data required for each individual pipeline location project.

Paper 1858 November, 1958 SU 3

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(Proc. Paper 1858)

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Highway and Bridge Surveys: Preliminary Survey.
(Proc. Paper 1697, July, 1958. Prior Discussion:
none. Discussion open until January 1, 1959.)
by William A. White 1858-3

Note: Paper 1858 is part of the copyrighted Journal of the Surveying and Mapping Division, Proceedings of the American Society of Civil Engineers, Vol. 84, SU 3, November, 1958.

HIGHWAY AND BRIDGE SURVEYS: PRELIMINARY SURVEY[a]

Discussion by William A. White

WILLIAM A. WHITE,[1] A.M. ASCE.—Keeping in mind that a manual prepared and published by ASCE should reflect a high moral standard, one should examine the statement made under the heading "Choice of Mapping Methods."

> "All-aerial surveys have the inherent feature, usually desirable, of concealing the details of probable location from those who would misuse such information for financial advantage. Ground-control work for aerial surveys reveals but little of the highway engineer's intentions."

It is natural and proper that highway engineers should not want their survey crews "pestered" by property owners asking questions which the survey crews are not able to answer; but the statement quoted does not recite a healthy reason for using photogrammetry. It implies instead that property owners are dishonest. It goes further and openly advocates secrecy in government. Is this a correct position?

Under the same general heading there is a paragraph headed "Procurement of New Maps." It is difficult to understand why this paragraph was written. Possibly it will have some historical interest to readers of the manual. Very probably the paragraph may not be an accurate statement for the comparative status of private and of public mapping organizations a few years from now.

Under the heading "Mapping Procedures" the 8th paragraph under "Ground Surveys" states:

> "The preliminary map prepared from the data gathered by the conventional ground survey method is usually called a strip map because it is plotted on a continuous roll of detail paper."

Apparently strip maps not prepared on a continuous roll of detail paper are illegitimate. If so, there are probably more illegitimate than legitimate strip maps prepared.

Finally it appears questionable that the expression "ground survey method" should always be preceded by the word "conventional" in the paper. Photogrammetry is of age now and most of its methods are also conventional.

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a. Proc. Paper 1697, July, 1958, Preliminary Survey.

1. Exec. Secy., California Council of Civ. Engrs. and Land Surveyors, Sacramento, Calif.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1449 is identified as 1449 (HY 6) which indicates that the paper is contained in the sixth issue of the Journal of the Hydraulics Division during 1957.

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NOVEMBER: 1426(SM4), 1427(SM4), 1428(SM4), 1429(SM4), 1430(SM4)[c], 1431(ST6), 1432(ST6), 1433(ST6), 1434(ST6), 1435(ST6), 1436(ST6), 1437(ST6), 1438(SM4), 1439(SM4), 1440(ST6), 1441(ST6), 1442(ST6)[c], 1443(SU2), 1444(SU2), 1445(SU2), 1446(SU2), 1447(SU2), 1448(SU2)[c].

DECEMBER: 1449(HY6), 1450(HY6), 1451(HY6), 1452(HY6), 1453(HY6), 1454(HY6), 1455(HY6), 1456(HY6)[c], 1457(PO6), 1458(PO6), 1459(PO6), 1460(PO6)[c], 1461(SA6), 1462(SA6), 1463(SA6), 1464(SA6), 1465(SA6), 1466(SA6)[c], 1467(AT2), 1468(AT2), 1469(AT2), 1470(AT2), 1471(AT2), 1472(AT2), 1473(AT2), 1474(AT2), 1475(AT2), 1476(AT2), 1477(AT2), 1478(AT2), 1479(AT2), 1480(AT2), 1481(AT2), 1482(AT2), 1483(AT2), 1484(AT2), 1485(AT2)[c], 1486(BD2), 1487(BD2), 1488(PO6), 1489(PO6), 1490(BD2), 1491(BD2), 1492(HY6), 1493(BD2).

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JANUARY: 1494(EM1), 1495(EM1), 1496(EM1), 1497(IR1), 1498(IR1), 1499(IR1), 1500(IR1), 1501(IR1), 1502 (IR1), 1503(IR1), 1504(IR1), 1505(IR1), 1506(IR1), 1507(IR1), 1508(ST1), 1509(ST1), 1510(ST1), 1511(ST1), 1512(ST1), 1513(WW1), 1514(WW1), 1515(WW1), 1516(WW1), 1517(WW1), 1518(WW1), 1519(ST1), 1520 (EM1)[c], 1521(IR1)[c], 1522(ST1)[c], 1523(WW1)[c], 1524(HW1), 1525(HW1), 1526(HW1)[c], 1527(HW1).

FEBRUARY: 1528(HY1), 1529(PO1), 1530(HY1), 1531(HY1), 1532(HY1), 1533(SA1), 1534(SA1), 1535(SM1), 1536(SM1), 1537(SM1), 1538(PO1)[c], 1539(SA1), 1540(SA1), 1541(SA1), 1542(SA1), 1543(SA1), 1544(SM1), 1545(SM1), 1546(SM1), 1547(SM1), 1548(SM1), 1549(SM1), 1550(SM1), 1551(SM1), 1552(SM1), 1553(PO1), 1554(PO1), 1555(PO1), 1556(PO1), 1557(SA1)[c], 1558(HY1)[c], 1559(SM1)[c].

MARCH: 1560(ST2), 1561(ST2), 1562(ST2), 1563(ST2), 1564(ST2), 1565(ST2), 1566(ST2), 1567(ST2), 1568 (WW2), 1569(WW2), 1570(WW2), 1571(WW2), 1572(WW2), 1573(WW2), 1574(PL1), 1575(PL1), 1576(ST2)[c], 1577(PL1), 1578(PL1)[c], 1579(WW2)[c].

APRIL: 1580(EM2), 1581(EM2), 1582(HY2), 1583(HY2), 1584(HY2), 1585(HY2), 1586(HY2), 1587(HY2), 1588 (HY2), 1589(IR2), 1590(IR2), 1591(IR2), 1592(SA2), 1593(SU1), 1594(SU1), 1595(SU1), 1596(EM2), 1597(PO2), 1598(PO2), 1599(PO2), 1600(PO2), 1601(PO2), 1602(PO2), 1603(HY2), 1604(EM2), 1605(SU1)[c], 1606(SA2), 1607(SA2), 1608(SA2), 1609(SA2), 1610(SA2), 1611(SA2), 1612(SA2), 1613(SA2), 1614(SA2)[c], 1615(IR2)[c], 1616 (HY2)[c], 1617(SU1), 1618(PO2)[c], 1619(EM2)[c], 1620(CP1).

MAY: 1621(HW2), 1622(HW2), 1623(HW2), 1624(HW2), 1625(HW2), 1626(HW2), 1627(HW2), 1628(HW2), 1629 (ST3), 1630(ST3), 1631(ST3), 1632(ST3), 1633(ST3), 1634(ST3), 1635(ST3), 1636(ST3). 1637(ST3), 1638(ST3), 1639(WW3), 1640(WW3), 1641(WW3), 1642(WW3), 1643(WW3), 1644(WW3), 1645(SM2), 1646(SM2), 1647 (SM2), 1648(SM2), 1649(SM2), 1650(SM2), 1651(HW2), 1652(HW2)[c], 1653(WW3)[c], 1654(SM2), 1655(SM2), 1656(ST3)[c], 1657(SM2)[c].

JUNE: 1658(AT1), 1659(AT1), 1660(HY3), 1661(HY3), 1662(HY3), 1663(HY3), 1664(HY3), 1665(SA3), 1666 (PL2), 1667(PL2), 1668(PL2), 1669(AT1), 1670(PO3), 1671(PO3), 1672(PO3), 1673(PL2), 1674(PL2), 1675 (PO3), 1676(PO3), 1677(SA3), 1678(SA3), 1679(SA3), 1680(SA3), 1681(SA3), 1682(SA3), 1683(PO3), 1684 (HY3), 1685(SA3), 1686(SA3), 1687(PO3), 1688(SA3)[c], 1689(PO3)[c], 1690(HY3)[c], 1691(PL2)[c].

JULY: 1692(EM3), 1693(EM3), 1694(ST4), 1695(ST4), 1696(ST4), 1697(SU2), 1698(SU2), 1699(SU2), 1700(SU2), 1701(SA4), 1702(SA4), 1703(SA4), 1704(SA4), 1705(SA4), 1706(EM3), 1707(ST4), 1708(ST4), 1709(ST4), 1710 (ST4), 1711(ST4), 1712(ST4), 1713(SU2), 1714(SA4), 1715(SA4), 1716(SU2), 1717(SA4), 1718(EM3), 1719 (EM3), 1720(SU2), 1721(ST4)[c], 1722(ST4), 1723(ST4), 1724(EM3)[c].

AUGUST: 1725(HY4), 1726(HY4), 1727(SM3), 1728(SM3), 1729(SM3), 1730(SM3), 1731(SM3), 1732(SM3), 1733 (PO4), 1734(PO4), 1735(PO4), 1736(PO4), 1737(PO4), 1738(PO4), 1739(PO4), 1740(PO4), 1741(PO4), 1742 (PO4), 1743(PO4), 1744(PO4), 1745(PO4), 1746(PO4), 1747(PO4), 1748(PO4), 1749(PO4).

SEPTEMBER: 1750(IR3), 1751(IR3), 1752(IR3), 1753(IR3), 1754(IR3), 1755(ST5), 1756(ST5), 1757(ST5), 1758(ST5), 1759(ST5), 1760(ST5), 1761(ST5), 1762(ST5), 1763(ST5), 1764(ST5), 1765(WW4), 1766(WW4), 1767(WW4), 1768(WW4), 1769(WW4), 1770(WW4), 1771(WW4), 1772(WW4), 1773(WW4), 1774(IR3), 1775 (IR3), 1776(SA5), 1777(SA5), 1778(SA5), 1779(SA5), 1780(SA5), 1781(WW4), 1782(SA5), 1783(SA5), 1784 (IR3)[c], 1785(WW4)[c], 1786(SA5)[c], 1787(ST5)[c], 1788(IR3), 1789(WW4).

OCTOBER: 1790(EM4), 1791(EM4), 1792(EM4), 1793(EM4), 1794(EM4), 1795(HW3), 1796(HW3), 1797(HW3), 1798(HW3), 1799(HW3), 1800(HW3), 1801(HW3), 1802(HW3), 1803(HW3), 1804(HW3), 1805(HW3), 1806 (HY5), 1807(HY5), 1808(HY5), 1809(HY5), 1810(HY5), 1811(HY5), 1812(SM4), 1813(SM4), 1814(ST6), 1815 (ST6), 1816(ST6), 1817(ST6), 1818(ST6), 1819(ST6), 1820(ST6), 1821(ST6), 1822(EM4), 1823(PO5), 1824 (SM4), 1825(SM4), 1826(SM4), 1827(ST6)[c], 1828(SM4)[c], 1829(HW3)[c], 1830(PO5)[c], 1831(EM4)[c], 1832(HY5)[c]

NOVEMBER: 1833(HY6), 1834(HY6), 1835(SA6), 1836(ST7), 1837(ST7), 1838(ST7), 1839(ST7), 1840(ST7), 1841(ST7), 1842(SU3), 1843(SU3), 1844(SU3), 1845(SU3), 1846(SU3), 1847(SA6), 1848(SA6), 1849(SA6), 1850(SA6), 1851(SA6), 1852(SA6), 1853(SA6), 1854(ST7), 1855(SA6)[c], 1856(HY6)[c], 1857(ST7)[c], 1858 (SU3)[c].

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c. Discussion of several papers, grouped by divisions.

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